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Bell Telephone MAGAZINE

Putting Disabled Veterans Back to Work • LAWRENCE L. ARMANTROUT

Twenty Years of 'Talking Movies': an Anniversary
FRANK H. LOVETTE and STANLEY WATKINS

Command Circuits • ELDON NICHOLS

Bell Laboratories' Rôle in Victory—Part II

American Telephone & Telegraph Company · New York

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"The ideal and aim of the American Telephone and Telegraph Company and its Associated Companies is a telephone service for the nation, free, so far as humanly possible, from imperfections, errors, or delays, and enabling anyone anywhere to pick up a telephone and talk to anyone else anywhere else, clearly, quickly and at a reasonable cost."

A Medium of Suggestion & a Record of Progress

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WALTER S. GIFFORD, *Pres.;* CARROLL O. BICKELHAUPT, *Sec.;* DONALD R. BELCHER, *Treas.*

Who's Who & What's What

in This Issue

"THE VETERAN who has a physical disability will be placed (and trained where necessary) on a job *which fits his particular qualifications,* not merely on a job he can do." So wrote LAWRENCE L. ARMANTROUT in "Welcoming Bell System Veterans Back to Work," which was published in the issue of this MAGAZINE for Spring 1945. That was the promise, made while this country was fighting enemies on two fronts. Now those wars are over, and he can measure the performance against the promise—as he does here. The facts which he sets forth speak for themselves.

Mr. Armantrout joined the Traffic Department of the Michigan Bell Telephone Company in 1925, and in the next dozen years held various assignments involving manual, dial, and toll operation. In 1937 he moved over to the company's Personnel Department, and in 1943 he transferred to the A. T. and T. Company's Personnel Relations Department. Since going to New York, he has been largely occupied with personnel matters arising out of necessary adjustments to military service and readjustments to peaceful employment.

Lawrence L. Armantrout

Frank H. Lovette

A WHOLE GENERATION exists today which knows nothing of silent movies. To these people, motion pictures naturally have dialogue, music, appropriate noise—just as automobiles have self-starters and radios have loud speakers. To them the change from silent motion pictures to today's inadequately nicknamed "talkies" is simply an accomplished fact. This younger generation is still outnumbered, however, by people who *experienced* the change, marveled at it, and appreciate how great is the advance, in artistry and interest, which came about two decades ago. The leading part which the Bell System played in the change is told in this issue's second article.

The entirely different backgrounds of the two authors have fitted well together to give their story historical authenticity. Before joining the Western Electric Company in 1943, FRANK H. LOVETTE had been—among other things—publisher of a daily newspaper, executive officer of the old Federal Radio Commission, secretary to a member of Congress, and the author of three books. His present post is that of Historian, and his preparations for the article included much research in old records, patents, and similar documents. To this MAGAZINE for Winter 1944–45 he con-

Stanley Watkins

tributed "Western Electric's First 75 Years: A Chronology."

STANLEY WATKINS joined the Bell Laboratories (then Western Electric Company's Engineering Department) in 1911, and his various activities there have included several years of active participation in the development of sound motion pictures, beginning in 1922. In 1925 he had charge of the Laboratories' group which installed and operated the first commercial sound picture recording system in the Vitaphone studios in Brooklyn; he was then for a year Vitaphone's chief engineer; and from 1927 to 1936 he was director of recording engineering and European technical director for ERPI. Since returning to the Laboratories in 1937, he has worked on a variety of projects; and his wide background and long experience are now being employed in the Laboratories' Publication Department.

SOME OF the places pictured in "Command Circuits" are doubly familiar to ELDON NICHOLS, for he saw them twice: once, under fire, as an officer in the Army Signal Corps; and, again, as a civilian expert sent out by the Long Lines Department to help reëstablish overseas telephone service with the United States. Probably even more familiar to him are the radio teletypewriter circuits he describes, for he looked at them from two sides: first as staff representative (overseas service) in Long Lines, where he took part in early work on radio teletypewriters; and again as Officer in Charge of Communications Facilities Engineering Section, Office of the Chief Signal Officer. Mr. Nichols assisted in the installation of the first chain of single-channel radio teletypewriter circuits through the Caribbean, South America, and Africa, and in communications planning in the Pacific Ocean and Southwest Pacific areas.

Mr. Nichols joined Long Lines in Boston in 1922, and three years later transferred to New York. There he filled several assignments in the Plant Department prior to the staff post (already mentioned) he held when he entered the Army, in 1942, as Captain. At the time of his release in November 1945 he was a Lieutenant Colonel. He was awarded the Legion of Merit for his work with the Chief Signal Officer, and received the Bronze Star Medal for feats performed during his tour of duty in the Pacific under General MacArthur. He returned from his civilian expedition to Manila and Tokyo last April, and is now circuit layout engineer at Long Lines' New York headquarters.

THE ACCOUNT of the many ways in which the Bell Telephone Laboratories contributed to Allied victory, which was begun in the preceding (Winter) issue, is concluded with the article beginning on page 116. Since these paragraphs are largely a compilation "from the record," their author may be identified most conveniently as that prolific and frequently quoted authority, ANONYMOUS. THE EDITORS

Eldon Nichols

Utility in a setting of peace and beauty: one of the joint Army-Navy radio stations on Guam. *See "Command Circuits," beginning on page 101*

Nearly 1,500 Former Employees and 700 Other Veterans With Service-incurred Disabilities Are on the Job with Bell System Telephone Companies

Putting Disabled Veterans Back to Work

Lawrence L. Armantrout

LET'S TAKE three instances, by way of illustration:—

The Kraut artillery had the range, and when the American tank started to cross the bridge they blew it off and into the water, where it lay partly submerged. Because it was under fire, the crew could not be rescued until darkness fell. Wounds and exposure caused injury to the tank captain's leg muscles which Army doctors rated, when he was discharged, as a fifty percent impairment of use of the legs.

A shell-burst got the infantryman before he could make the foxhole, and messed up his right leg. It had to come off, finally—below the knee. Now he wears an artificial leg.

Jap gunfire never got to a certain Marine during all his service in the Pacific, but malaria did. It was the recurring type, and with it came headaches which at the time of his discharge were rated as incapacitating.

Those three men were Bell System employees serving their country on military leave of absence. Now they are back on the job again, doing good and useful work and happy in the doing of it.

They are cited here because they bring out an important point in connection with the reëstablishment of disabled veterans on the job. That is, the wide variety of situations the telephone companies run into as they work with their returning employees to find the right job for every individual.

Matching disabled veterans and suitable jobs is only one part of the Bell System's general program for placing all returning employees in the right assignment *; but it is a highly important part. Specifically, its major objective is to put the veteran on a job *for which his particular qualifications fit him*—and not merely on a job he may be able to do.

* See "Welcoming Bell System Veterans Back to Work," MAGAZINE, Spring 1945.

Nearly 1,500 Have Some Degree of Disability

THAT'S THE TARGET. How close to the bull's-eye are we shooting?

Suppose we add up the score so far, and look at the figures.

Up to July 1 of this year, more than 32,000 employees had returned from the Armed Forces to the operating telephone companies of the Bell System. Those who incurred some degree of physical disability while in the service are of course a relatively small proportion of the total: 1,488, or about four percent.

Of that figure, 16 represent amputations; 118, impaired sight or hearing; 421, disabilities involving some restriction of movement; and 933, almost two-thirds of the group, disabilities such as tropical diseases, conditions of the heart or nerves, arthritis, and other ills which, while incurred in the service, are not caused directly by wounds.

That isn't the total reckoning, however. For in addition to welcoming back the 1,488 men just enumerated, the telephone companies have been proud to hire another 689 veterans, not previously employed, who have some degree of disability. Of this group of new employees, 14 have had amputations, and nearly a quarter of them have a disability which causes some restriction of motion.

Statistically, those figures total 2,177. But the statistics are significant only as a measure of the opportunity. What *is* important is 2,177 men, individuals: each with his own problems, his own hopes; each to be placed on the job he can do best.

It wasn't all new to the System—this business of placing disabled employees on work they are equipped to do. The System has been operating for a good many years, and has gained some experience both with men whose disabilities developed in the course of their employment and with men who were employed with some physical impairment.

That experience was sound and helpful; but, the telephone companies realized, it wasn't enough. So, within the general program for welcoming the returning veterans, they set up a special program for the veterans who would return bearing in some form the scars of war.

THAT SPECIAL PROGRAM fell naturally into three sections: *planning, doing,* and *checking.* Let us see what is involved in each.

Planning. The first step was to review past experience in placing employees with physical limitations, to see what could be learned there for future application.

Then came a re-analysis, thorough and detailed, of the physical requirements of the various occupations of the business.

From this could be derived the relationship between various kinds of physical limitations and the kinds of work that could be done with—or in spite of—those limitations.

Then, to corroborate theory, one company fashioned an adjustable device which, when strapped to the body, could produce the effect of physical restriction on various parts of the body. The actual effect of different kinds of simulated limitations was observed on the performance of various types of work operations, and the results of this study were made known throughout the System.

Whatever information was available outside the business was freely consulted. The reports and studies of the Armed Forces, the Veterans Administration, and the War Manpower Commission were found particularly helpful.

Doing. The facts about job requirements developed during the planning phase have been of the greatest practical value to the people who have the actual responsibility for making the assignment of the veteran to the specific job.

No less important has it been to find out the disabled employee's physical capacities, his interests, and the range of his present and potential capabilities.

The employee's *physical capacity to do* can thus be matched against the *physical requirements of several specific jobs,* and the *selection of the particular job* made on the basis of *his particular interests and capabilities.*

Such hand-and-glove fitting is by no means an automatic process. Since we are dealing with human beings—individuals, personalities—and not objects nor statistics, it calls for the closest kind of coöperation between people who do the job assigning, the Medical Department, and people in other supervisory positions.

Out of it comes not just assignment to a job which the employee can do with safety to himself and others, but to a job where he can have the satisfaction of using fully his particular qualifications and of making his most effective contribution to the success of the business.

Checking. Since the process is human and not automatic, the program includes regular follow-up of each man and his job, to see that things go along smoothly: that the adjustment to civilian life and productive employment is made easier for him; that if he needs training, it is made available to him.

This follow-up is the responsibility of supervisors within each department. If a specific problem arises, the solution is found and constructive action taken—with the coöperation, as required, of those responsible for placement and the Medical Department.

Most Men Return to Their Old Jobs

THOSE ARE generalizations. It is possible to be quite specific in describing the kinds of jobs in which veterans with disabilities have been placed.

Such matters as this determine whether the program is a success—whether the reality lives up to the intent.

Let's see what the record shows.

Of the 1,488 employees who came back with some degree of disability, more than 1,000 have been returned to the jobs they held before entering the Service, without the need for making any change in the scope of the job or the functions it includes.

In 72 instances, it has been necessary to revise some of the functions of the job or to limit the employee to doing only certain parts of the job. For example, certain disabilities prevent former installers from climbing, although they are entirely competent at every other function of the installer's work. In many instances it has been possible to assign these men

to areas where climbing isn't necessary.

New jobs have been found for 314 disabled employees. Most but not all of these re-assignments were necessitated by the inability of the men to do their former work competently and safely. In 90 percent of these instances, the employee's maximum wage rate for the new occupation is the same as or higher than for his old job. In the remaining 10 percent, which have a lower ultimate wage, the companies are making every effort, through special training, to fit the men for assignments which will compare with their old jobs. Up-grading has already been possible in more than half of these instances.

Twenty-four employees have disabilities which have rendered them at least temporarily unemployable. They have been reinstated and placed on disability under the companies' Benefit and Pension Plans. There is expectation that before long some will be able to do productive work.

Adapting the Man and the Job

ASSIGNMENT to new jobs has been most necessary, generally speaking, in those occupations which require outdoor activity and muscular effort or a good deal of mobility. To a lesser extent, inability to do certain operations requiring manual dexterity has been a factor.

Of the 16 employees who underwent amputations, seven are doing effective work on their old jobs. One man is back at his old job, somewhat revised, at the same rate of pay. Eight have been placed in new occupations, at the same rate or better. Of that last number, here are some examples:

A combination-man lost a leg and wears an artificial one. He was trained and is functioning as a central office repair man.

An installer who lost his left hand was trained and then placed as a plant assigner.

Another installer suffered the loss of the four fingers of his right hand —although the thumb remains useful. He was given special training to develop the necessary dexterity in his left hand, and is now performing all the functions of the installer's job, including climbing, without apparent handicap.

OF THE 421 employees whose disability involved restriction of motion of some part of the body, about one-third have been placed on different jobs. Examples of this type of shift:

An installer suffered loss of strength and muscle balance in both legs. For a while he was placed on disability, and subsequently was given facilities assigning work. But his physical improvement was such that within six months he could resume all the functions of his old job—and did.

A house service man's leg was so severely injured that it became immobile. He was given training for and then assigned to a clerical job.

An installer whose back injury brought about restricted bodily motion was first placed in sedentary work as a general clerk; but improvement in his condition made it possible to place him as a line assigner, and there is good prospect of still another job—as a central office repairman.

A construction groundman's injury

resulted in partial paralysis of the right arm. He was re-trained as, and now is, a central office repairman.

A sales manager had his foot badly crushed. But that injury did not affect his ability to do his old job.

Of the 118 employees who returned with impaired sight or hearing, all but 16 have been placed in their old jobs. There were no cases of total blindness and only two of total deafness—and the latter are able to handle their old jobs satisfactorily.

In the largest group—933—whose disabilities included tropical diseases, conditions of the heart or nerves, arthritis, and similar ills, assignment to different jobs was necessary for less than 20 percent. In most instances these involved a necessary change from installation or construction work to jobs requiring less physical exertion.

The 689 newly employed veterans with some degree of disability have all been placed on jobs in which their disabilities present no insuperable handicaps, and so they may look forward to contributing successfully to the progress of the business and themselves.

THE STORY of placing disabled veterans where they will do the very best jobs they can for themselves and their companies is necessarily told here in terms of generalities and a few anonymous instances.

There are other contributing factors to the accomplishment of the program which must not be overlooked.

The attitude of "supervision," from foreman to president, has been constructive and helpful.

All of those who have had the important responsibility for bringing the right man and the right job together have exercised imagination and ingenuity not only in doing that part of the job but in developing special kinds of training when needed.

Fellow employees have contributed immeasurably in understanding and encouragement—both those who have returned sound and whole to their old jobs and those who, because they played their parts on the home front, feel forever indebted to the men who laid down their tools to take up arms.

But the greatest contribution comes from the men themselves. By their eager coöperation in finding the right assignment, their indomitable will to rise above whatever physical limitations they may have, they give the rest of us convincing demonstration that "disability" is not necessarily synonymous with "handicap."

The Sciences and Techniques Which Have Contributed to the Constant Progress of Telephony Had By-products which Culminated in 1926 in Sound Motion Pictures

Twenty Years of 'Talking Movies': an Anniversary

Frank H. Lovette and Stanley Watkins

TWENTY years have now passed since the night of August 6, 1926, when Western Electric and Bell Telephone Laboratories, in collaboration with Warner Brothers Pictures Inc. and the Vitaphone Corporation, gave to the world that by-product of telephone research which has often been called *the living voice of the silver screen.*

That memorable occasion, which the Bell System joins Warner Brothers in observing, was the premiere of the world's first successful commercial sound picture, *Don Juan,* featuring the noted actor John Barrymore. It was preceded by short film presentations of opera stars and musicians—the first time a theater audience had heard the natural tones of music and the human voice from a motion picture screen.

There were distinguished guests in Warner Brothers' New York theater that night—among them a score or more of the scientists and engineers of Western Electric and Bell Telephone Laboratories who had labored for years to perfect the devices which were combined in the apparatus about to receive its first public demonstration. If some of them were anxious, it was understandable: the crucial test was at hand.

Then, as the theater lights were dimmed, symphonic music burst from the screen while the first of the short preliminary features appeared on it: the New York Philharmonic Orchestra playing the overture from Wagner's *Tannhäuser.* Next came Mischa Elman, playing *Humoresque* upon his violin. Roy Smeck, Marion Talley, Zimbalist, and Bauer performed in succession. With a full orchestral accompaniment the noted Metropolitan Opera artist Giovanni Martinelli sang

The big night: August 6, 1926. The first public performance of the first successful sound motion picture on Broadway was an event, as this crowd indicated

the aria from *Pagliacci*. Anna Case, singing in an elaborate Spanish fiesta set, climaxed the prelude.

Before the applause could die away, the dramatic sequences of Don Juan unfolded against their synchronized musical background. Scientists, public officials, prominent figures from many walks of life sat in amazement until the last crescendo and finale of this scientific marvel. The men who brought it into being by their refinement of existing arts were hailed as having made possible "the greatest invention of the twentieth century." And Dr. Michael I. Pupin was led to exclaim that "no closer approach to resurrection has ever been made by science." The pioneers of Western Electric and Bell Telephone Laboratories and their collaborators of Warner Brothers and Vitaphone experienced that night a measure of accomplishment which few men of science ever live to taste or see.

THAT WAS the climax, the culmination. The purpose here is to recall the state of the arts as they existed when Western Electric undertook development of sound pictures, and to review the steps by which they were brought to commercial acceptance.

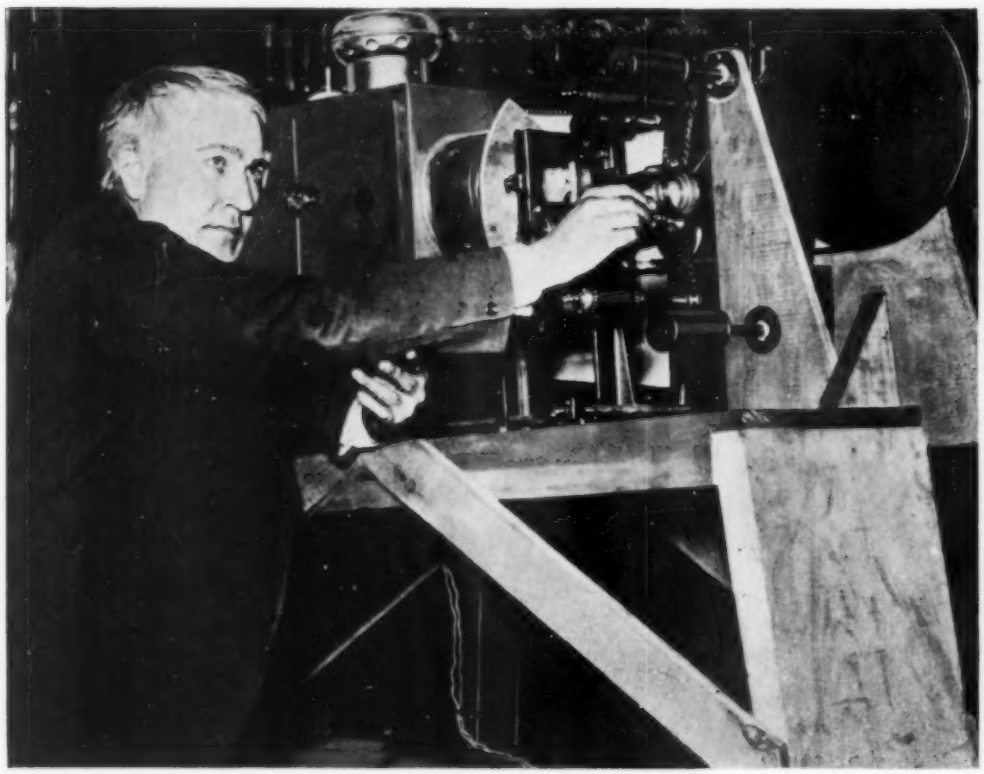
THE ACHIEVEMENT of a satisfactory technique for recording and reproducing sound synchronized with motion pictures had been a cherished ambition of science for more than fifty years.

Distinguished inventors, engineers, physicists and chemists, men proficient in photography and the mechanical arts, as well as a veritable army of tinkerers, had followed the gleam of that rainbow, but none had found its end. They could not; for, however great may have been the contributions of these earlier experimenters to the advancement of the silent film, they completely lacked five essential elements of the modern talking picture:

1. A high-quality microphone capable of transmitting a wide range of sound frequencies without distortion and of being used at a distance from the performer.
2. A non-distortive amplifier.
3. An electrical recorder and reproducer.
4. A loud-speaker of high quality and adequate capacity.
5. A synchronizing system free from speed variation.

AS LATE AS 1912, the science of modern electro-accoustics was yet unborn, and no efficient instrument for the measurement of sound was available.

It was in October of that year that Lee deForest, a former Western Electric engineer who had left the company to pursue a career as an independent inventor in the field of "wireless," submitted to Dr. Frank B. Jewett—then assistant to Western's



Irving Underhill

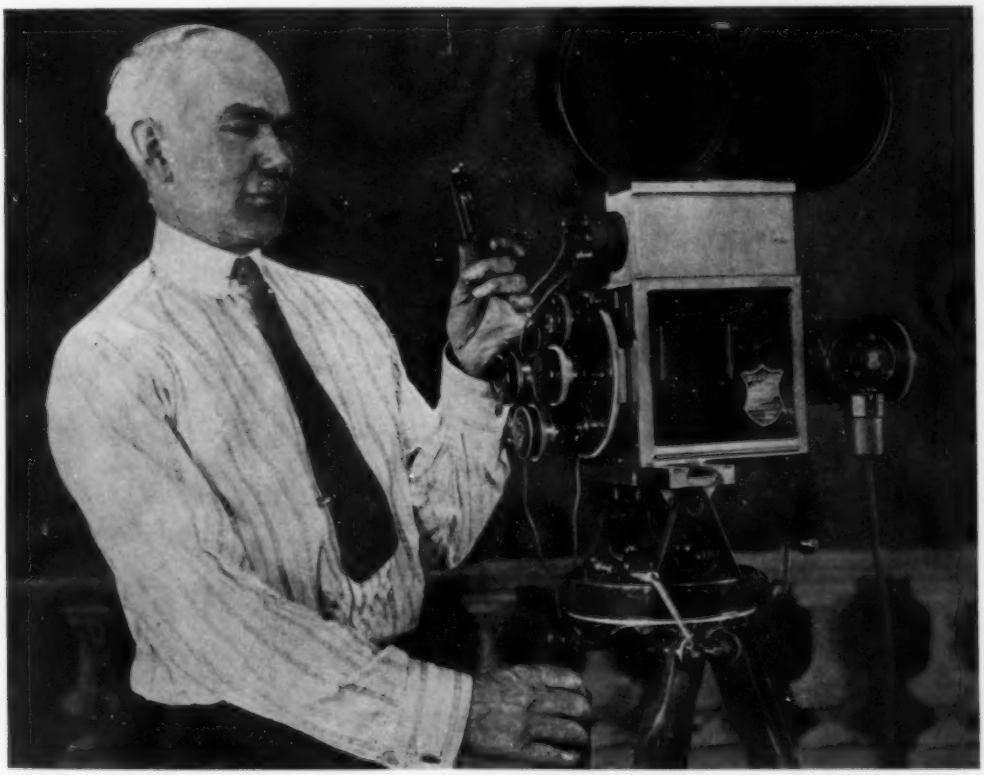
Thomas A. Edison working in his West Orange laboratory in 1905 on the problem of synchronizing sound and pictures

Chief Engineer, Charles E. Scribner —a little device which was to be of momentous importance to the Bell System. It was the "audion," which was ultimately to provide the solution to the System's problem of finding a practicable "repeater" for its long distance circuits.

The development of a satisfactory repeater was a primary objective of telephone engineers in this country and throughout the world. Out of it would come the telephone's final conquest of distance on this earth. So there were hours of intense discussion among deForest, Jewett, and E. H. Colpitts about such things as the audion's capabilities, the tests to which it had already been submitted, its adaptability to commercial manufacture, the proprietary interests of certain others in it, and similar preliminaries.

Finally, it was agreed that the audion should be tested by Bell System engineers. If it performed in accordance with the high hopes of all, Jewett assured deForest that he would recommend its purchase on the basis of terms the inventor had tentatively suggested.

Late that afternoon when deForest said goodbye to his friends at 463 West Street, he left his audion behind him. He did not dream that he had also left the magic key with which a



Brown Brothers

Lee deForest. His audion became the magic key which unlocked the doors of a new scientific age

little group of telephone engineers would unlock the doors of a new scientific age.

Jewett had a great ambition to achieve transcontinental telephony, to which an effective repeater would be essential, and one of the young engineers on his staff, H. D. Arnold, was working on the problem.

Soon after deForest left his audion to be tested, Jewett summoned Arnold and showed him the device. The young engineer silently and critically examined the audion while his chief explained its background.

Finally Arnold declared, "It will do it."

He hastened to point out what steps he thought would have to be taken to increase the audion's efficiency. Both the outer circuit leading into the tube and the inner circuit would have to be redesigned. It was weak in output because the chamber had not been completely evacuated, and the higher vacuum could be obtained only with a pump superior to the one deForest had used. Needless to say, Arnold got the assignment to refine and develop the audion.

Although his analysis proved accurate and his 1912 conception had to be altered but slightly, he could not build a high vacuum tube until 1913, when he obtained a satisfactory vacuum pump from Europe. In the spring of that year, the Bell System purchased the audion.

Testing the Audion

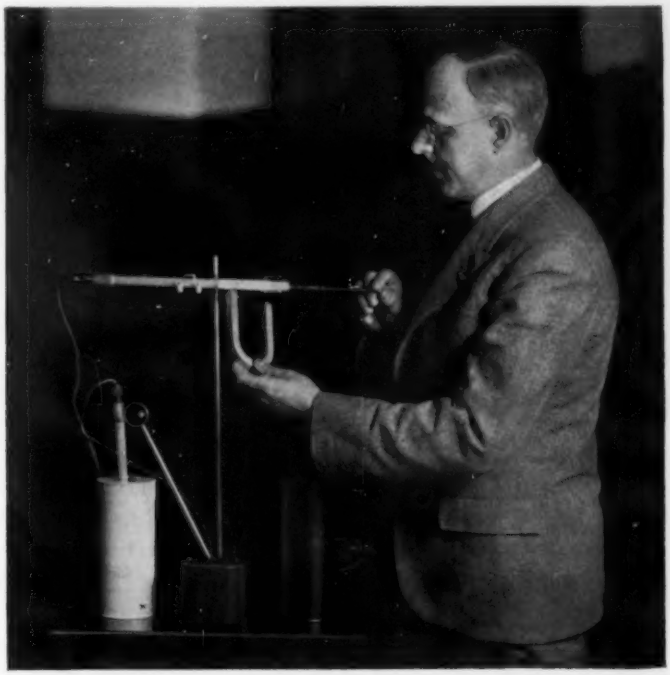
COINCIDENT with the acceptance of the audion came the need for qualified young scientists to augment the existing research staff; for it was evident that the audion was potentially capable of revolutionizing the art of communication, and that its capabilities had to be explored extensively as well as intensively.

The vacuum tube—as the audion had now become—had to be tested on long lines and short lines. Its components had to undergo scores of laboratory tests. Research had to be conducted in more than one hundred particulars.

During those exciting and busy months in the Western Electric Engineering Department, Jewett, Colpitts, E. B. Craft, Arnold, I. B. Crandall and their associates decided to record sound for its use as a laboratory tool. Transcontinental telephony would require much more than just a first-class repeater. Higher quality transmitters and a wide variety of associated apparatus had to be designed. Much of it might be tested and compared by use of acoustical recordings. The recordings would also serve to help appraise successive developments of the vacuum tube and demonstrate its performance as an amplifier.

This new approach to achievement of improved transmission, together with these original and fundamental studies of sound, marked the beginning of the science of electronic amplification.

Talking pictures were not contemplated by the engineers initiating these fundamental studies of sound. However, they believed it imperative to obtain recordings of higher quality than those available by the commercial processes of the contemporary phonograph industry. They decided, therefore, to experiment with the recording of sound upon film (an old but non-commercial laboratory art) while simultaneously seeking to im-



Harold D. Arnold. His development of deForest's audion into the high-vacuum tube met the Bell System's pressing need for a practicable repeater for its long distance circuits

prove the wax disc method of recording.

The broad scientific attack projected by this program contained a great variety of complex elements. After the fashion of a modern military invasion, the generals and their subordinates had to divide and sub-divide their respective responsibilities.

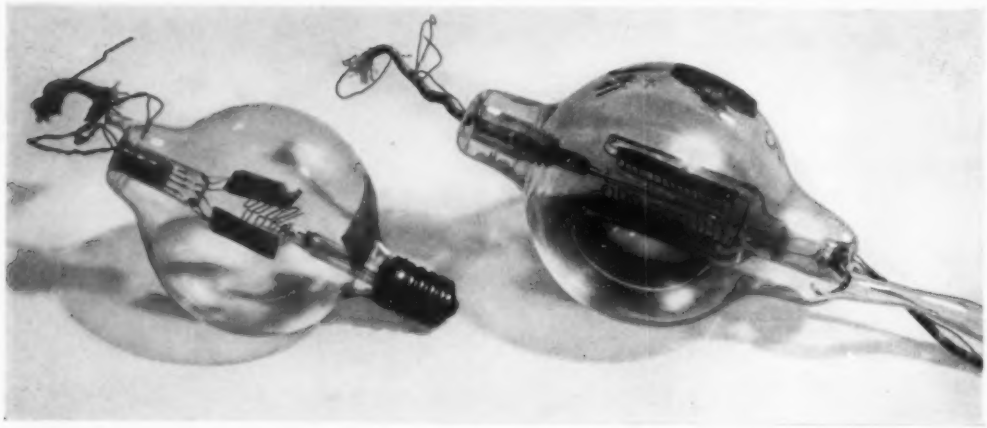
While Arnold attacked the audion, other Western Electric engineers, using an improved microphone and a Duddell Oscillograph, recorded sound upon film in the winter of 1912-13. These first recordings were of the variable area type.

Early in 1913, H. A. Frederick began work upon instruments for transmission of music, and soon thereafter the engineers Crandall and Kranz began construction of an electro-magnetic phonograph reproducer. Experiments were continued with both film and disc. Most of these engineers pursued uncharted pathways. Their original notebooks, still preserved, reveal the minutely detailed and frequently dramatic results of this research.

Improving the Microphone

MEANWHILE, a number of young engineers had been welcomed into Western Electric's Engineering Department: alert, ambitious youngsters, eager to put their university-acquired knowledge to practical use. Among these newcomers was Edward C. Wente, who arrived in 1914.

When young Wente had been there a few months, he was given a microphone by Arnold and Crandall. It was the highest quality electro-magnetic transmitter known to telephone engineers; it represented the cumulative



DeForest's audion as submitted to Dr. Jewett in 1912 (left), and the high-vacuum tube developed in 1913 for the first telephone repeater

effort expended in this field since Bell's invention of the telephone. His superiors explained to Wente the nature and extent of his first major assignment. The microphone had to be made capable of transmitting music, and this required its development to a hitherto unattempted quality. The frequency range of music was wider and its loudness range much greater than that of speech. One obstacle to constructing such a microphone was the lack of any available means of accurately measuring its performance.

About the time Wente was ready to consult Arnold and Crandall concerning the feasibility of a device he had conceived for microphone calibration, he found them too busy to help him. It was late in 1914, and 463 West Street was suddenly plunged into a whirl of activity and excitement. The vacuum tube repeaters were working on the long lines to Denver. Soon came the tests between New York and San Francisco. The new repeaters worked with equal effectiveness!

The high-vacuum tube was just getting started on its triumphs. On September 29, 1915, Bell System engineers provided a world sensation by transmitting human speech between Arlington and Honolulu. Less than one month later, on October 20, 1915, this feat was duplicated between Arlington and the Eiffel Tower in Paris. Telephone engineers had registered a scientific achievement which was hailed as one of the most important in history.

The New Repeater Succeeds

THE AUDION had started the whole program, and no one concerned was more elated than deForest. In a paper afterward for the Franklin Institute, he referred to the Western Electric engineers as follows:

The developments by the engineering staff of the Western Electric Company of the audion amplifier as a telephone repeater, since my first demonstration to them of its possibilities in that field, are beyond all praise. The zeal and rare understanding of the elements of the problem with which this staff of trained men developed

the amplifier and applied it to the long-sought trans-continental telephone line stand unique in the annals of brilliant achievement in electrical engineering.

THE TRANSCONTINENTAL and trans-oceanic conquests accelerated telephone research in all its subdivided fields. When Wente presented his case for the need of a microphone-calibrating instrument to Arnold and Crandall, they aided him in the design and construction of it. This instrument, called the thermophone, permitted accurate measurement of microphone performance for the first time.

Until then, the microphone had been the source of power, and therefore it had to be designed for the highest possible efficiency. The power from the microphone had to be sufficient to provide electrical impulses of enough strength to produce the required volume when the electric current was translated into sound at the receiver.

Arnold's high-vacuum tube amplifier made it possible to sacrifice efficiency for the sake of quality. Accordingly, Wente concentrated upon a microphone which would give uniform response at the various pitches in the audible range. His thermophone permitted quantitative measurements at each individual pitch. By 1916 he had developed the condenser microphone. It gave uniform response up to more than 15,000 cycles, and left little to be desired from the standpoint of quality. Both his thermophone and condenser microphone were adopted as standard by the International Reference System for Telephony located in Paris. For his condenser microphone he received the John Price Wetherell medal of the Franklin Institute. In an

E. C. Wente. His condenser microphone was one of the foundation stones on which sound motion pictures were built

article published in the *Physical Review* in 1917, Wente pointed out the advantages of his condenser microphone for recording sound upon film.

Accomplishments of Four Years

DURING Wente's early research, the recording of sound was receiving a fresh impetus from the success and future possibilities of the high-vacuum tube.

In June 1915, Arnold suggested making phonograph records with a high-quality transmitter and amplifier, pointing out the exceptional results which had been obtained by use of the Frederick transmitter in conjunction with a vacuum-tube amplifier during transmission tests between Denver and New York. Crandall and Kranz had used their electrical reproducer experimentally in 1914. By 1915, superior electrical reproducers were in use with phonograph records, but the records themselves had not been made electrically; in other words, not by a method employing a high-quality wide-frequency-range microphone and amplifier.

On June 24, 1916, Crandall reported to Colpitts that one of the engineers in his group had made recordings of sound on film by the variable density method. They were of such surprising quality, he concluded in his written report: "I see no reason why a method for producing talking pictures of fair quality cannot be developed."

Thus, by 1916, Western Electric engineers had:

1. Refined the audion into the high-vacuum tube. (1913)
2. Given the vacuum tube its first commercial application by opening transcontinental telephone service. (1915)
3. Demonstrated trans-Atlantic radio telephony between Arlington and the Eiffel Tower. (1915)
4. Recorded sound on film by the variable area method. (1912-13)
5. Recorded sound on film by the variable density method. (1916)
6. Constructed improved electrical reproducers for the wax-disc phonograph. (1914-15)
7. Developed the condenser microphone. (1916)

In less than four years of coöperative research, Bell System scientists had produced this impressive array of engineering achievements. Modern talking pictures beckoned at the threshold. The prospect was tempting to those who had journeyed so far in that direction. But the crossing of that threshold suddenly was made quite impossible because the awful specter of World War I hung darkly over American shores. In that same year, 1916, the Bell System was called upon to arrange a vast mobilization of the nation's major communications facilities. The military preparedness program began. Not until the war was over was it possible to devote further research to the electrical recording and reproduction of sound.

Post-War Projects

WHEN THE Western Electric engineers were able to return to telephone research, their fundamental studies of sound were resumed under Dr. Jewett's guidance.

Arnold and his assistants inaugu-

rated a score of projects involving the vacuum tube — which, incidentally, had come a long way during the years of war. Wente resumed his work upon the condenser microphone and, together with Crandall and others, conducted a new experiment in the recording of sound on film. At this same time another group, headed by J. P. Maxfield, undertook improvement of the technique of recording on wax discs.

E. B. Craft had been associated with development work since coming to Western Electric in 1902. Now that he had become one of Dr. Jewett's assistant chief engineers, he proved a stimulating factor in expediting and coördinating the various research projects. A high-quality public address system became one of his first objectives. The condenser microphone and vacuum-tube amplifiers and receivers, already devised by Western's engineers, needed little more than proper adaptation and redesign for commercial purposes to make such a public address system possible. The so called "loud speakers" were in reality loud-speaking telephone receivers.

Developments in Loud Speakers and Recording Sound

WITHIN A FEW MONTHS after the return of peace, a public address system was a laboratory reality. But the system of 1919 was not sufficiently free from distortion. By 1920 it was greatly improved; and in March 1921, 125,000 persons clearly heard every word of President Harding's inaugural address through the Western Electric public address system.

Eight months of improvement and experimentation made possible the

J. P. Maxfield (center), whose group developed electrical sound-on-disc recording which was used in the musical scoring of Don Juan, and is still used throughout the phonograph industry. With him are H. C. Harrison and D. G. Blattner

use of the public address system in connection with long distance wires. President Harding's address of November 11, 1921, at the burial of the Unknown Soldier at Arlington, epitomized one of the most significant ceremonies in American history. His words were transmitted through the public address systems at Arlington and—via long distance circuits—to audiences at Madison Square Garden and the adjoining park in New York and the Civic Auditorium and Plaza at San Francisco. More than 150,000 heard the address: the greatest audience that had ever listened to a single speaker.

Another great stride toward sound pictures had been accomplished.

During the previous year Wente had been working on the recording of sound upon film by the variable density method. The 1912-13 recordings upon film had been by the *variable area* method. Those of 1919 were made by the *variable density* method. The two methods have been briefly summarized as follows:

"In *variable density* recordings, the motion picture film is moved at right angles to a narrow slit, mechanical or optical, through which over its whole length there falls upon the film a light varying in intensity with the sound pressure to be recorded. In *variable area* recording, there is a like slit, but what varies with the sound pressure is the length of the part of the slit through which a constant light reaches the film. When completed, the *variable density* record viewed lengthwise looks like a ladder with rungs spaced according to the pitch and darkened according to the loudness of the recorded sound. The

E. B. Craft (left) making a sound picture for demonstration, at the Vitaphone Studios in the Manhattan Opera House in 1926. He exhibited the first electrically recorded sound picture in 1922

variable area record, viewed from the edge of the film, looks like a hedge with uneven trimming, having peaks and pits corresponding in height to the loudness and in spacing to the pitch of the sound recorded."

Upon first undertaking the variable density method, Wente considered various devices which had been proposed. It appeared to him that the method being used in that year, 1920, by Professor Rankine of England, for speech transmission over a light beam might provide the most correct film exposure. He made certain modifications of the device and constructed an instrument of similar type. The quality of his recordings compared favorably with that of the commercial phonograph records, but that did not satisfy Wente or Arnold. Wente finally concluded that the method did not permit correct film exposure. His next step was to devise the new and improved light valve in 1921-22. The device gave ample exposure even at high camera speeds, and removed the biggest single stumbling block to the successful recording of sound on film by the variable density method.

Since the war, Wente had devoted a part of his time to improvement of his condenser microphone. By 1923 it was about 100 times more sensitive than his first condenser microphone of 1916; and either the condenser microphone, or a high-quality carbon microphone employing a method of damping of the diaphragm discovered in the development of the condenser transmitter, was in use in public address systems and from the beginning in all the important radio broadcasting stations.

A Momentous First

IN 1922 Western Electric stepped up commercial production of microphones, vacuum tubes, public address system units, and various types of radio apparatus. The infant radio broadcasting industry developed a lusty voice. The American public was rapidly being captivated by the new entertainment art.

Craft now decided to step in front of the field by producing a talking motion picture. The group under Maxfield, using the new condenser microphone and improved vacuum-tube amplifying devices, had developed electrical recording by the wax-disc method to a greatly advanced stage.

Accordingly, Craft produced the first electrically recorded talking picture, which employed the new method developed by his engineers. It was exhibited in October, 1922, at Woolsey Hall of Yale University in New Haven.

This picture itself was accompanied by a transcribed lecture which explained the audion. The recorded voice of the speaker came from the screen with so natural a quality that the assembled students and scientists suspected a hoax. All were amazed when the recorded speaker, a Western Electric engineer, appeared upon the stage while his recorded voice came from the screen.

Improvements in Techniques

THE NEW HAVEN success inspired Craft to produce "Hawthorne," a picture with sound on disc portraying Western Electric's rôle as the manufacturing unit of the Bell System. This, the first industrial sound picture, was shown at the Hotel Astor at a

dinner given by Western's President, Charles G. DuBois, to 250 Bell System officials on February 13, 1924. The apparatus had been notably improved since the New Haven demonstration and now included an automatic synchronizing system in place of the manual method used at New Haven. Synchronization of the phonograph with the motion picture was not new, but the problem of designing a synchronous drive free enough from speed variations to be used with the high-quality electric records was a tough one. It was overcome by the groups under H. M. Stoller, H. Pfannenstiehl, and Maxfield.

A dominant factor in the solution of the drive problem was the mechanical filter developed by H. C. Harrison. He developed the high-quality disc reproducer, and also the "rubber-line recorder" which became the standard for high-quality disc recording. These devices represented an entirely new method for handling mechanical problems by the analogous electrical transmission techniques. The Harrison contributions to the development of talking pictures were outstanding.

The Orthophonic Phonograph

MEANWHILE, another portion of Maxfield's group determined better methods of controlling acoustics during sound pick-up by practical applications of methods learned from the use of the Western Electric public address system and from analysis of studio design and sound pick-up at the A. T. & T. radio station, WEAF.

Thus, early in 1924 Western Electric had a phonograph and recordings, in the laboratory stage, which reproduced speech, song, and instrumental music with fidelity and hitherto-unexampled tonal beauty. Many who heard it, including Thomas A. Edison, left the demonstrations with praise which ran to superlatives.

That same year the new method of electrical recording and reproduction was demonstrated to both the Columbia and Victor phonograph companies. After Columbia and Victor had experimented with the new method for several months, the so-called orthophonic phonograph came into being; it included an ingenious six-foot folded logarithmic horn within a phonograph cabinet. Both Columbia and Victor were licensed by Western early in 1925 to use the new method.

Recording Sound on Film

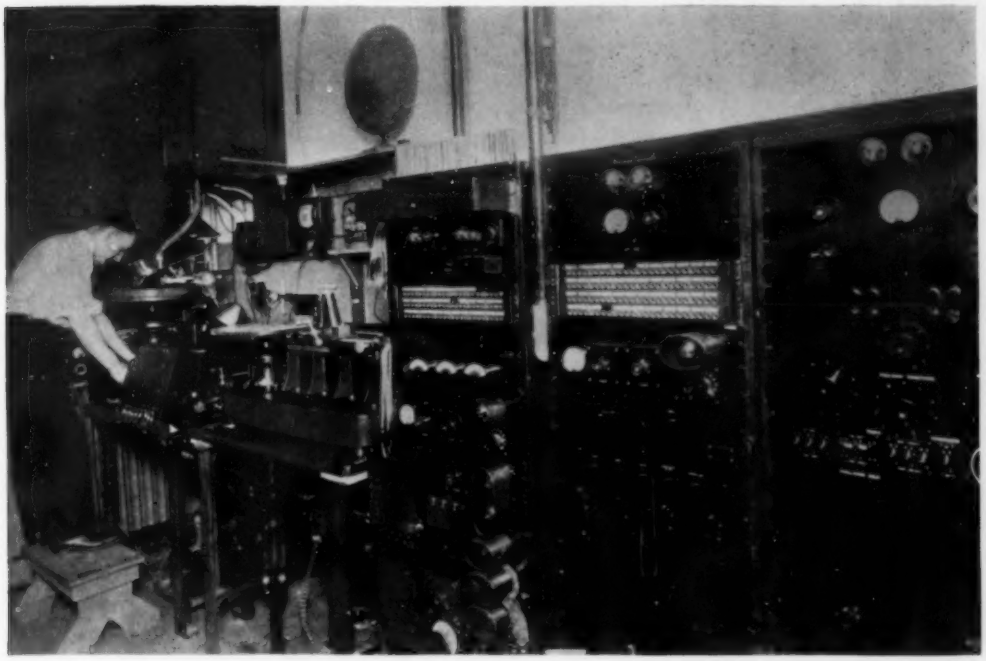
DURING the developments leading up to the orthophonic phonograph, other Western engineers steadily advanced the art of recording sound on film.

Donald MacKenzie's studies of photographic emulsions and the treatment of film had commenced in 1922.

In 1923, equipment was devised for synchronizing the film recorder and motion picture camera by means of an electrically operated gearing.

In that year Wente and MacKenzie made broader studies of emulsions, the problem of printing positives from negatives, amplifiers, the characteristics of light-sensitive devices, acoustics of recording studios, and microphone placement for sound pick-up.

In May 1923, Maxfield's group was making synchronized talking pictures with local talent speaking, singing, and playing musical instruments. In October 1923, a synchronized picture and sound-on-film recording was made and exhibited to members of the laboratory. In November 1923, a one-act



"Cutting a disc" in 1926. The apparatus at the left is engraving sound vibrations on a wax disc, duplicates from which will be played in synchronism with a film

sketch was similarly photographed and recorded.

By March 1924, MacKenzie concluded that better results would be obtained in recording sound on film by using a positive emulsion instead of the high-speed negative emulsion employed up to that time. The motion picture industry was then using a relatively coarse-grained negative emulsion of great light sensitivity and consequently of great speed.

The development of Wente's light valve, with its ability to modulate a light of relatively high intensity, enabled use of a much finer grained emulsion and lower speed, thus obtaining a sound record of improved quality and frequency range with much less background noise. The recording on positive emulsion was later to become standard practice in the motion picture industry.

IT WILL be seen that co-incident with mastery of the art of sound on disc, Western Electric's engineers had also by early 1924 solved the basic problems of recording sound on film. The quality of the sound reproduction obtainable from the two methods was about the same. But the disc method was an improvement of an old commercial art and had the immense advantage that the processes for preparing, handling, and duplicating the discs were well known; while for processing sound-film, an entirely new technique had to be introduced into the film plants, involving changes in the method of developing and printing the pictures themselves.

This situation, coupled with a prospective dual commercial outlet for musical recordings from motion picture productions, predetermined the use of disc recording in the introduction of sound pictures.

A few of E. B. Craft's advisers urged immediate commercialization of the Western Electric sound picture system in 1924. He declined, preferring to await more rigid tests of the equipment in actual or simulated commercial operating conditions. He well knew the difficulties which had been encountered in previous attempts to introduce talking pictures.

Noteworthy attempts to produce commercially acceptable sound motion pictures had already been made by these individuals and organizations:

By synchronism of phonograph and projector

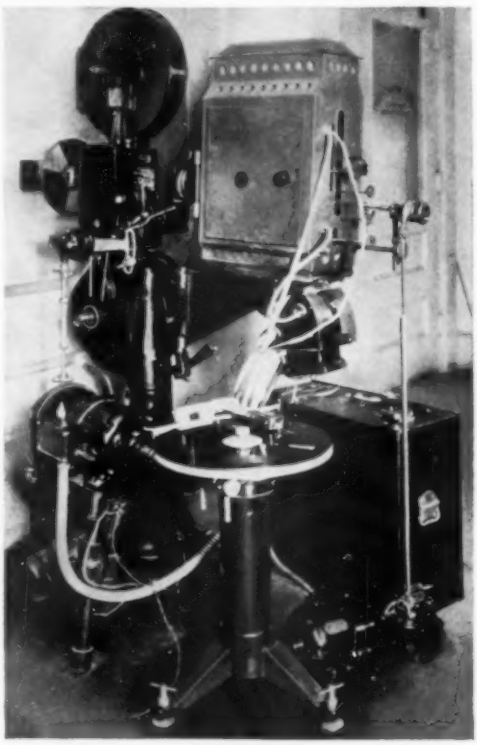
Thomas A. Edison.....U.S.A. and Europe
Pathé Frères.....France and U.S.A.
R. and E. Singing Picture Company. U.S.A.
(J. B. Russell Muselaphone System)
Webb Talking Pictures.....U.S.A.
(J. B. Russell Muselaphone System)
Cartella Talking Picture Machine Company .....Italy and U.S.A.
(Western Electric receivers and transmitters)
C. H. Verity Talking Moving Picture System .....U.S.A.
(Veritiphone)
Leon Gaumont .....France
Orlando E. Kellum .....U.S.A.

By sound on film

Eugene Lauste...France, England, U.S.A.
Tri-Ergon Corporations
Europe and U.S.A.
Lee deForest.....U.S.A. and Germany

DURING THIS testing period, Craft decided to produce a series of musical shorts with professional talent. An exciting period followed. Individuals with motion picture backgrounds, inventors, actors, musicians, promoters, and many others found their way to 463 West Street. Those who reached Craft or his assistants volunteered a thousand varieties of advice and service. Some were admitted to demonstrations. A few made helpful suggestions.

Craft told all who sought to commercialize the apparatus or to effect a Hollywood tie-up that Western Electric would consider any reasonable proposal. He promised to try to protect the interests of any who aided Western Electric in commercializing the apparatus. But to all he declared the Company desired to make the



"The Works." Said a Western Electric announcement of the time, "This projection machine gives a motion picture audience both visual and audible entertainment . . . Absolute synchronism of film with reproduced sound having a naturalness never before attained . . ."

apparatus available to the entire motion picture industry. He therefore favored a responsible intermediate agency capable of performing that function.

Authentic representations were made as to the superiority of Western's new sound picture technique, and offers for its commercialization were vigorously solicited. But by the end of 1924 practically every major producer in Hollywood had rejected Western Electric's sound picture system.

Obstacles to Commercial Use

THE WESTERN ELECTRIC engineers were not discouraged by Hollywood's indifference. Behind it lay valid reasoning.

The motion picture producers had large inventories of silent films, which had cost millions to produce. They had great numbers of actors and actresses under long term contracts, most of whom knew no dramatic technique except that of pantomime. The industry was universally equipped with stages and studios suited only to the silent film technique.

Moreover, world-wide foreign markets had been established for silent films. To serve these markets, it was merely necessary to translate the words printed upon the film from English to any language desired. Finding stars and supporting casts who spoke the various languages of the world, or finding ways to give the illusion of their speaking them, appeared to be an insuperable task.

The art of the silent film had attained superb quality and the public was satisfied. Why then, producers asked, should Hollywood scrap the bulk of its assets, undertake staggering conversion costs, and force upon the public a new and doubtful experimental art?

Nor were the exhibitors equipped for sound. Many, it was argued, would not be able to meet the cost of sound picture equipment.

These rebuffs had no effect upon the zeal of Craft and his associates, and they continuing to carry on their work after the Western Electric Engineering Department was incorporated as Bell Telephone Laboratories at the end of 1924.

AN ALTOGETHER fortuitous visit of a Western Electric field engineer to the Laboratories at 463 West Street determined the immediate future of sound pictures.

One day early in 1925 Nathan Levinson, Western's radio specialist from the Pacific district, arrived at the Laboratories to familiarize himself with the newest developments in radio and public address equipment. Levinson had aided Samuel L. Warner in the purchase and installation work of radio station KFWB, established by Warner Brothers a short time before at Los Angeles. He had worked in close relationship with Sam Warner, and their collaboration had led to a warm friendship.

During his visit to West Street, Levinson attended a sound picture demonstration provided by Maxfield, and saw one of the musical shorts Craft had produced in 1924.

The film began with a pianist entering a studio. Levinson heard the natural sounds of his steps; he heard clicks as he unbuttoned his gloves, the realistic sound when he tossed aside cane, hat, and coat. Then the performer sat down and commenced to

play. The music of the piano flowed from the screen with startling reality.

Levinson was an astute engineer who knew sound. What he now saw and heard was to him genuinely thrilling. His face shone with admiration when the lights were turned on, and he pronounced it wonderful. Before he left the studio, his active brain was formulating a plan to bring Sam Warner to West Street.

A few weeks later Levinson visited Sam Warner in Hollywood.

He told Warner he thought the Western Electric Company had the complete solution to the sound motion picture. He declared that the synchronization and quality of the demonstration he had witnessed were so striking that he was confident that an organization with the facilities and technique of Warner Brothers, working with Bell Telephone Laboratories' engineers, could produce such colorful productions as *"Rose Marie,"* the record-breaking musical comedy hit then on the New York stage. The great musicals of Broadway, world-famous orchestras, grand opera, and kindred entertainment luxuries of metropolitan centers could be taken to Main Street and the rest of the world by means of sound pictures.

Sam Warner assured Levinson he would accompany him to a demonstration on his next visit to New York.

"The Greatest Thing in the World"—Sam Warner

WESTERN ELECTRIC had by this time invested heavily and over many years in sound picture development. It was felt that decisive steps should now be taken to make the system available to the motion picture industry. Walter J. Rich of New York was a highly recommended applicant who proposed organization of an intermediate corporation to commercialize sound pictures. On May 27, 1925, Western concluded a limited contractual agreement with Rich for that purpose.

Levinson arrived at West Street with Sam Warner early in June. The best description of Sam Warner's reaction to the demonstration is to be found in the telegram he sent to his brother Harry after he had returned to Hollywood without telling any of his brothers what he had seen and heard. That telegram read:

GO TO THE WESTERN ELECTRIC COMPANY AND SEE WHAT I CONSIDER THE GREATEST THING IN THE WORLD.

Harry went. His report of the visit was a telegram to his brother Sam. It read:

I THINK YOU ARE RIGHT.

On June 25, 1925, Walter J. Rich and the Warner brothers made an agreement under which Rich assigned to Warner Brothers a half interest in his contract with Western, Warner Brothers agreeing to furnish the motion picture studio, associated equipment, and necessary personnel for an experimental program.

FOLLOWING this contract, Western's equipment was installed in Warner Brothers' Vitagraph studio in Brooklyn. In the experimental period, which lasted several months, the Bell System engineers worked in close collaboration with staff men of Warner Brothers. When all parties to the experimental arrangement were convinced that results justified commercial effort, Rich and the Warner brothers organized the Vitaphone Corporation. On April 20, 1926, a license agreement

between Western and Vitaphone was concluded. The Vitaphone Corporation was authorized to sub-license the various producers in the motion picture industry.

Warner Brothers thereupon staked their all upon the Western Electric sound system. The Manhattan Opera House was leased for the scoring of Don Juan and the making of various specialties for the premiere.

The premiere of Don Juan was widely heralded. Warner Brothers' New York theatre had been selected for the great first night of sound. Western Electric engineers and helpers worked for weeks installing the necessary equipment.

Meanwhile, Wente and A. L. Thuras, who had been working on a new type of loud-speaker, were able to complete its development in time for the Don Juan premiere. The new speaker had a practically uniform response from two octaves below middle C of the piano to about one-half octave above the highest note. It was from 50 to 100 times as efficient as the loud-speakers previously available. This contribution by Bell System engineers, one of whom had worked almost 12 years on the basic elements comprising sound pictures, helped insure the success of that great first night whose anniversary is now being observed: that first night whose history has been recounted here.

Climax and Beginning

DON JUAN was the climax of the Bell System's part in the *development* of sound motion pictures; but it was only the beginning of the art and the industry which have grown from it and in which Bell Laboratories and Western Electric have continued to play an important part.

Much has happened since: the op-

Western Electric equipment was installed in the old Manhattan Opera House to record the sound for the Vitaphone premiere—notably the scoring of Don Juan. This photograph shows a lull between "takes" of an operatic "short" in which Anna Case sang and the Cansinos danced

On Broadway in 1926

position to sound films by both producers and exhibitors, which in 1928 suddenly reversed itself and became a tremendous demand for equipment; the increasing adoption of the sound-on-film method of reproduction, which is practically universal today; the modification of arrangements with Warner Brothers and Vitaphone, and the establishment of Western's subsidiary, Electrical Research Products Incorporated, in 1926 to handle the Company's activities in the sound picture field; ERPI's withdrawal from the theater equipment field in 1937 when it licensed other manufacturers; and the further change when in 1941 it became a division of Western Electric; the growth to more than 16,000 sound-equipped theaters in this country today and to nearly three times as many in the rest of the world at last count.

Those and many other facts are matters of recorded history; but the history of the last 20 years is beyond the scope of this narrative.

WHAT is set down here is but a salute to the pioneers of the industry: to the scientists and engineers of Western Electric and later of Bell Laboratories, whose recognition and development of certain telephone by-products gave the world one of its most popular forms of entertainment; and to the Warner brothers—Sam, Harry, Albert, Jack—and their associates, who had the vision and the courage to become the first producers of commercially acceptable sound motion pictures. Together they shared a rich experience.

Multi-channel Radio Teletypewriter Circuits Developed by The Bell System and the Signal Corps Were the Backbone of Army Communications with Theaters Overseas

Command Circuits

Eldon Nichols

IN THE PENTAGON BUILDING a Signal Corps technician stands before a steel table. In his hand is a paper tape on which is printed an official radiogram. Beneath the printed letters there are small holes to actuate a machine which is blind but has sensitive fingers of steel. The technician inserts one end of the tape in a slot, and it rapidly disappears. At the same moment a similar tape, bearing the identical printed message, emerges from another slot at Frankfurt, Germany. This is only one of six messages speeding on their way to Frankfurt, and six others are arriving simultaneously in Washington from there. In all, 720 words are crossing the Atlantic every minute between these two points, over one radio circuit.

From nearby tables, messages are making similar flights to London, Paris, Algiers, and Asmara; and from those points some of them take off again for Tehran, Moscow, New Delhi, and Chungking. Other messages take wire lines to San Francisco and then jump directly to Hawaii, Manila, or Tokyo.

Obviously, there is more to this than meets the eye. The little machine that snatches paper tape from the hand of the operator is merely a gateway leading into a complex array of telegraph, telephone, and radio devices collectively known as a multichannel radio teletype system. This system did not exist before the War. It was born in December, 1941, and grew to maturity within a few short months. Before its first birthday it had become the backbone of the vast network of overseas radio circuits of the Army Communications System.

Over this system flashed the words which General Eisenhower impatiently awaited—the words which released the flood of American might that ultimately washed over the Westwall and into Berlin. And over this system General MacArthur received the green light for the fulfillment of his two great ambitions—his return to Manila and his entry into Tokyo as Supreme Commander.

The main radio transmitting station in Algiers. Directional antennas beamed toward it were ready for the invasion of North Africa

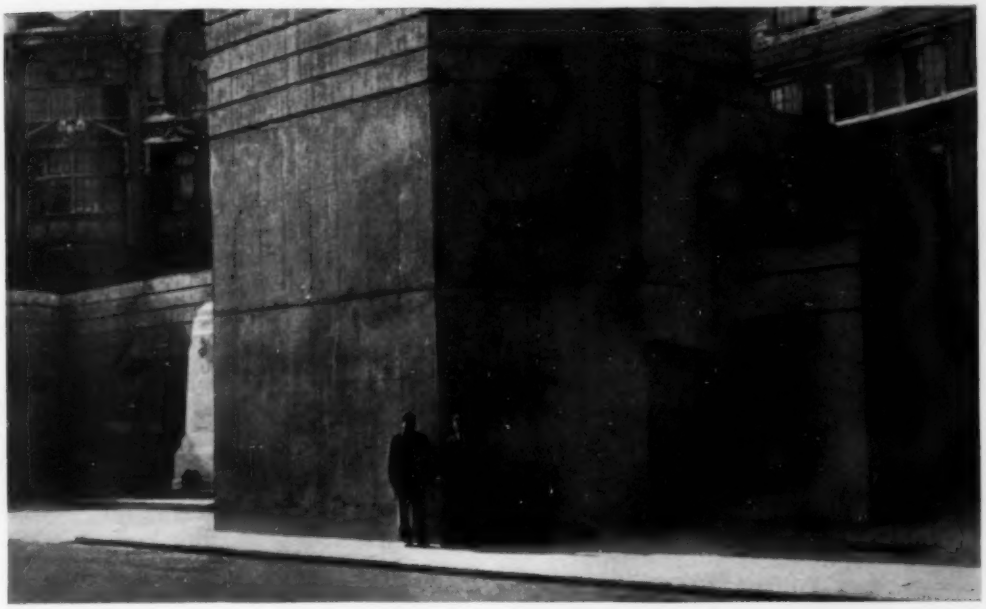
Radio's Advantages

SUCH MESSAGES as these, of course, formed but a small part of the almost incredible total of fifty million words a day carried by the great Army network. There were requisitions for urgently needed supplies, manifests detailing the cargoes of ships, reports of military operations, news items from home for the Stars and Stripes and the Pacifican, and all too often there were long casualty lists. All of these messages were essential to the successful conduct of the War—and it is inconceivable that they could have been handled without radio teletype.

Radio was chosen as the principal medium for overseas war communications because of its mobility. Submarine cables normally carry the bulk of the telegraph traffic over a number of important routes, such as between the United States and England. In wartime, however, cables are at a disadvantage except when they connect allied nations in areas where the enemy is not in a position to interrupt them. The invader can seldom count on them as a means of communication with his bases in the rear because his stepping-stones are often places of little peacetime importance which are not reached by cables. And if there happens to be a cable terminal in the invader's path, it is usually destroyed before he reaches it. It takes much time and skill to lay a new cable or to repair an old one, and in waters within the range of enemy aircraft or submarines such work is likely to be both costly and uncomfortable.

FOR THESE REASONS, radio was the more practical medium in most situations confronting our forces in World War II. But radio has its shortcomings too, and some of these had to be surmounted before it could take the leading role.

Before the War, radio messages



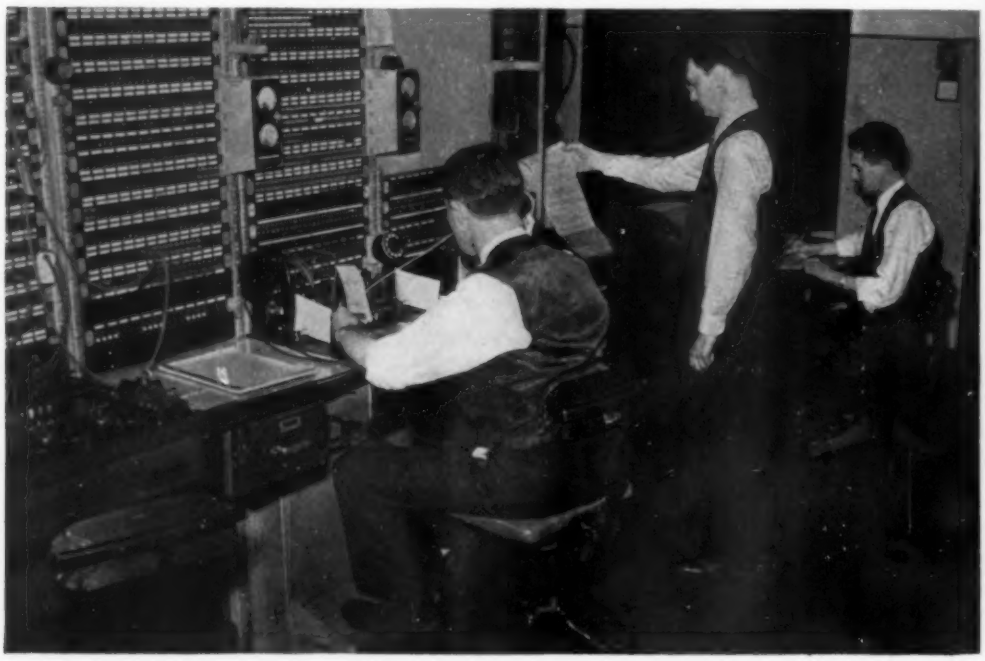
In London: Entrance to the Allies' radio control center, set up under ground because of the blitz

In Paris: The Germans had thoughtfully bomb-proofed this building before it was taken over as Allied communications center

were usually sent in the dots and dashes of the International Morse code, either with telegraph keys and head receivers or with tape transmitters and recorders. By the latter method, very high speeds can be attained under ideal radio conditions, but often the speed is severely limited by weak reception, static, or fading, and generally ranges between 20 and 200 words per minute. For the higher speeds, several highly skilled operators are required, and the training of such an operator usually takes from six months to two years.

Naturally, the obvious benefits to be gained by using printing telegraph devices, such as the teletypewriter, on radio circuits had interested several organizations before the War, and considerable work had been done in this direction. This work had been moderately successful, and regular operation had been established over a few of the more favorable radio paths. However, the fading and static gremlins had prevented the extensive use of "printers" in radio.

DURING the Battle of Britain, the British Government became fearful that the Germans might interrupt several of the cables between the United States and England. This would throw the entire load on the existing radio circuits, most of which were subject to interruption in the winter months by electromagnetic storms. The American Telephone and Telegraph Company and the British General Post Office jointly operated a long-wave radio telephone circuit between New York and London. This circuit is usually at its best when short



The Army's multi-channel service gets close attention at the Long Lines Department's telegraph testboard in Washington

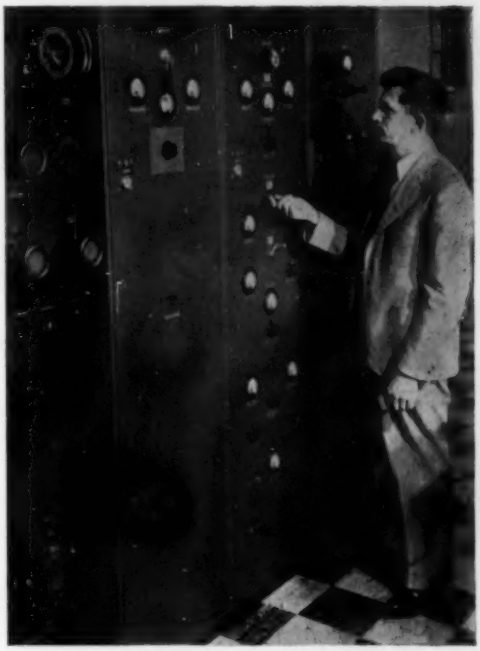
waves are at their worst. The British Post Office therefore proposed a plan for establishing several emergency telegraph channels on this radio circuit. Tests were made; and though the channels were far from perfect they were well worth while as an emergency measure, so the plan was adopted and arrangements were made to use it if necessary. Although this need never arose, an idea had been born, and speculation began in the Long Lines Department as to other possible applications of this technique.

Trials Prove Successful

SUDDENLY this interesting train of thought was turned in a new direction by the bombing of Pearl Harbor, and our immediate entry into the War. The Army would surely need overseas communications beyond all precedent. Overseas telephone service with enemy-held countries had been suspended, leaving high-grade radio facilities and expert technicians available for other purposes. How could these assets be employed to meet the Army's need?

In a small conference at Long Lines headquarters in New York, an executive asked: "Do you think we could operate a voice-frequency carrier telegraph system on a short-wave radio circuit, just as we did in the British long-wave emergency plan?"

The first responses to this question were discouraging. It was pointed out that short-wave signals often vary or fade a thousand-fold in strength at intervals of only a second or so. Long waves are not afflicted by this malady, yet the results of the long-wave tests had been only fair. But someone said, "Well, it wouldn't do any harm to make some tests, would it?" So it was decided to try, before giving up, and within a few days experimental work on the multi-channel radio teletype system began.



A Long Lines overseas radio transmitter on the Atlantic coast. Employment of the Bell System's experienced civilians at such posts released Army technicians for duty elsewhere

Although far from satisfactory, the initial tests showed great promise, and stimulated further efforts. More men were assigned to the project, and the Bell Telephone Laboratories and the Department of Operation and Engineering were invited to participate—which they most wholeheartedly did. Ideas for improvement sprang from all sides. Within a short time an experimental system between New York and San Francisco was working so well that the power of the radio transmitter in Cal-

ifornia could be reduced to only 25 watts—barely enough to light a small lamp—and still good teletype copy would be received in New York!

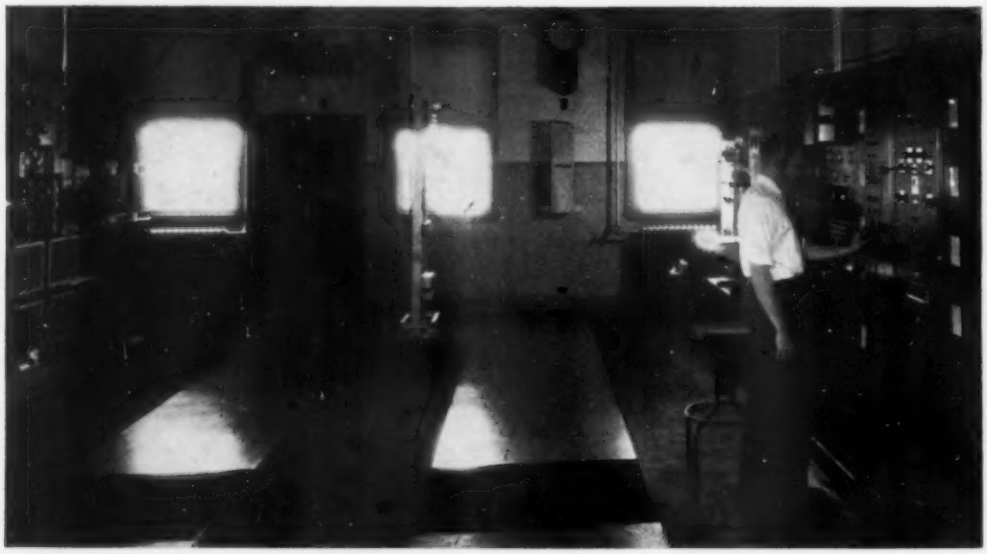
It was noteworthy that this radically new and phenomenally successful system was created almost entirely of standard units of Bell System equipment, thoroughly tried and tested by long experience and available on short notice. First, there was the single-sideband radio transmitter and receiver, used for more than a decade in overseas telephone service. Then there was the voice-frequency carrier equipment which had long been used in Morse and teletype service. And, of course, there were the familiar teletype machines, used throughout the nation for TWX and private line service.

To these basic ingredients, a few simple but highly important additions had been made. The result was a novel communications system which overcame to an almost unbelievable extent the effects of fading, static, and interference.

Demonstrating the System

WITHIN a few weeks the development work had reached the stage where success seemed certain, and Brigadier General Frank E. Stoner, Chief of the Army Communications Service (later a Major General and Assistant Chief Signal Officer), was invited to inspect the experimental system. His reaction was not only favorable but enthusiastic, and he requested that a plan for the use of the system in the Army be submitted for consideration.

This plan, which was promptly furnished, proposed that the Long Lines Department provide the radio and carrier facilities in the United States,



Overseas radio receiving equipment in California. Long Lines provided the radio stations and the channels to the Signal Centers in Washington and San Francisco, while the Army enjoyed full operational control of the movement of its traffic

together with wire line telegraph channels between the Long Lines radio stations and the Army Signal Centers in Washington and San Francisco, and that the Signal Corps purchase corresponding equipment from Western Electric for installation at Army headquarters overseas. Thus, the Army would have full operational control over the movement of traffic, sending and receiving all messages with its own personnel in the War Department; yet it would be relieved of the necessity of building radio stations in the United States, and expert civilians would take the place of Army radio technicians, releasing them for duty elsewhere.

It was further proposed that service be established at a very early date between Washington and European Theater headquarters in England by obtaining the coöperation of the British General Post Office in London. This organization, which had initiated the long-wave emergency plan, was known to have the major items of equipment required, as well as excellent engineering talent.

THESE PROPOSALS were placed before Major General Dawson Olmstead, then Chief Signal Officer, and were quickly accepted. Engineers, installers, and technicians on both sides of the Atlantic rolled up their sleeves, and on the desired date, July 18, 1942, the London system was on the air. Meanwhile, the manufacture of a number of complete terminals, specially arranged in transportable cabinets for installation by Signal Corps men overseas, had been started by Western Electric and was well under way.

Finding Personnel for the Overseas Installations

THE DIFFICULTY of selecting and training technical personnel for the overseas installations was recognized at the outset. To help solve this problem, the names and last known locations of about 60 Army officers and enlisted men, on military leave of absence from the Bell System, were given to the Army. These men were known to have excellent backgrounds for further training in the technical features of the multi-channel system. The importance the Army attached to the project is attested by the fact that nearly all of these men were promptly released from their current assignments. Even a captain assigned to the Air Forces and wearing pilot's wings was included.

An intensive six-week training course was quickly organized, and officers and enlisted men were hurried to Long Lines headquarters in New York, where a school was opened. First the students were given lectures on the theory of the system, and practical experience with the terminal equipment. Then they were hurried off to Long Lines radio stations at Lawrenceville, Ocean Gate, Netcong, and Manahawkin for further training on radio transmitters and receivers. This school was so successful that it was continued through nearly the entire duration of the War and, in all, 394 men were trained.

These men attracted such favorable attention overseas that a number of them were taken out of the multi-channel teams after their installations were completed, and were

Station W A R, Washington. In this section of the Signal Corps' message center, messages are being punched on tapes for automatic transmission

placed in other important assignments. Initially each team was led by a captain, but all of these team captains and several of their subordinates were later promoted into the field grades, and the ex-pilot became a colonel.

For "Asmara," Read "Algiers" Instead

BY RUSHING the manufacturing work and by diverting equipment originally ordered for other purposes, Western Electric soon completed the first units for installation overseas. Since Long Lines was providing the equipment in the United States, including highly directional antennas beamed accurately toward the corresponding overseas station, close coördination was essential; yet in some cases the need for secrecy was great. In one instance this conflict between coördination and secrecy led to an ingenious hoax.

The Army confided to a few Long Liners that one of the first installations would be in Asmara, East Africa, and requested that antennas aimed at that point be constructed. This was done, but meanwhile another unit had been shipped, to an unknown destination. As time passed, a Long Lines official became concerned lest this second shipment might arrive at its destination and be ready for service before the antennas in the United States were built. Almost daily he called this situation to the attention of a Signal Corps officer in Washington, who always replied: "Don't worry, we'll give you time enough."

On the morning following the announcement to the world of the invasion of North Africa, the officer telephoned the Long Lines man. "We are going to start service soon with a new point," he said. "You can use the antennas you have already built. Look at the globe near your desk and I think you can guess the name of the place."

Examination of the globe showed

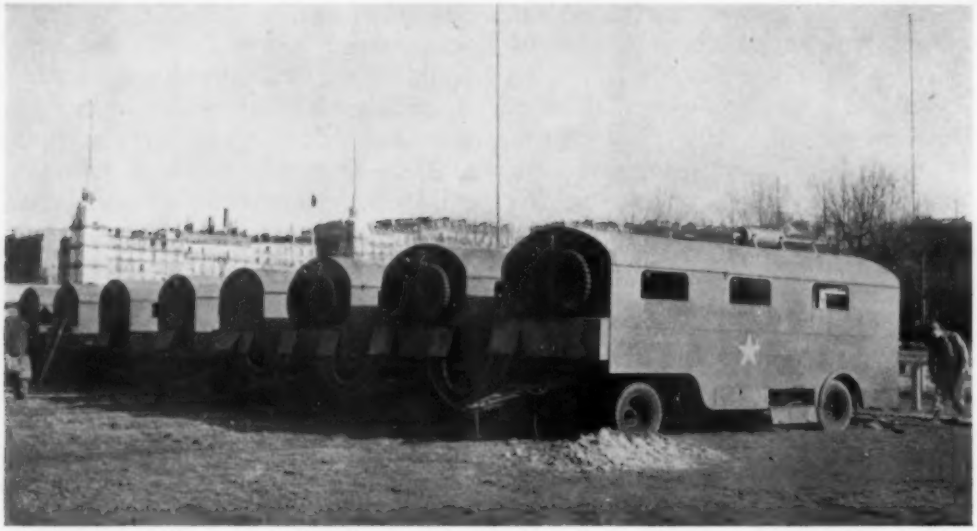
another point, almost exactly "on the beam" between Washington and Asmara. That point was Algiers. The secret had been kept—yet the antennas were ready.

Soon Long Lines technicians were waiting anxiously, hoping that the men and equipment had arrived safely, and wondering when Algiers would be on the air. They did not wait long. A voice said: "This is Freedom testing," and presently messages direct from Eisenhower's new headquarters were pouring into the great Signal Center in the Pentagon, which is aptly named Radio Station WAR.

Asmara, however, had not been named for deception alone. A system to that point was established soon afterward. Direct radio transmission between Washington and points as far east as Tehran and New Delhi is only feasible during a very short period in each day. Asmara served as an important relay station, insuring rapid and reliable communication with the Persian Gulf Command and the China-Burma-India Theater.

OTHER INSTALLATIONS followed rapidly. When it was decided that the major effort of the Allied Forces would be directed across the Channel instead of in southern Europe, a team and equipment already in the Mediterranean were quickly shipped out through Gibraltar and up to England to augment the facilities planned for France. A system was established between London and Algiers, creat-

Here Signal Corps personnel are attending the automatic transmitting (foreground) and receiving machines



"Sigcircus": A complete communications unit, equipped as a mobile station to keep pace with Headquarters as it moved forward

ing a triangle whose apexes were Washington, London, and Algiers, and providing an alternative route between any two of these points. A second system, with Signal Corps equipment in England, was set up between Washington and London, and before D-Day a capacity of more than a million words a day was available over direct channels between these two great capitals.

The Mobile "Sigcircus"

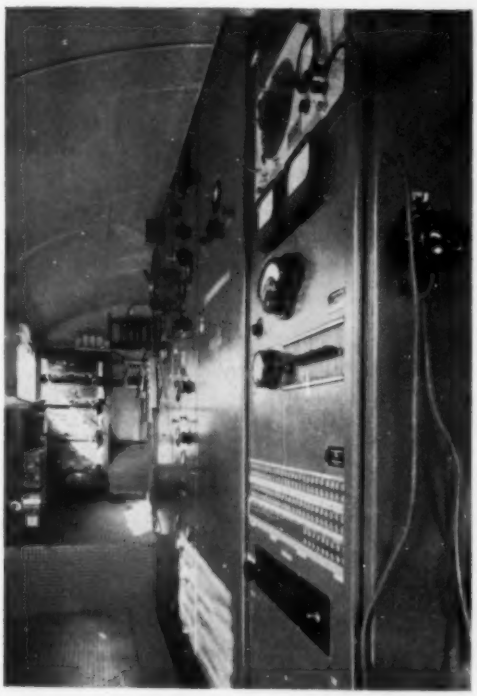
WELL in advance of D-Day, three complete units were made ready for use on the European continent. One of these was to be held in reserve as protection against possible combat losses. The others would permit "leap-frogging." One of them would be installed at main headquarters. Then, as soon as a forward echelon had been established, the second unit would be installed there. When main headquarters moved up to the forward echelon location, the unit left in the rear would be dismantled and made ready to "leap-frog" forward to a new location. To facilitate these moves, one of the equipments was installed, near Paris, in a complete mobile station mounted in 18 trucks and trailers, ready to move forward into Germany. In accordance with the Signal Corps practice of using the prefix "SIG" on certain kinds of equipment, this caravan was dubbed "Sigcircus."

Plans for the future employment of the multi-channel units were made and revised continually to meet changes in the strategic situation. With the "drying up" of North Africa and the establishment of a firm foothold in France, the London-Algiers system was no longer needed. But the War in the Pacific was advancing at a faster pace, and more facilities were needed there. So the Algiers terminal was shipped back

to Western Electric, reconditioned, reshipped, and finally was installed in Manila.

This was by no means the only installation of multi-channel equipment in the Pacific. The first system had been placed in operation in Brisbane, Australia, in March 1943, and remained in service there until the summer of 1945, when it was dismantled and "leap-frogged" northward to meet a need for service much farther forward—in Tokyo.

Three terminals were installed in Hawaii in bomb-proof tunnels built shortly after the Pearl Harbor disaster. Two of these worked with San Francisco, the third with Guam. In addition to the usual Army traffic, some channels of these systems were extended to Navy headquarters, one was used for air traffic control, and others made it possible for the Joint Chiefs of Staff to maintain almost instantaneous contact with the Twentieth Air Force units whose swarms of B-29s reduced Japanese industry to ashes. "Bombs away" signals from B-29s over Japan were picked up at Guam and flashed on to Washington so quickly that it is likely that the news reached the Pentagon before the first bomb struck the target.

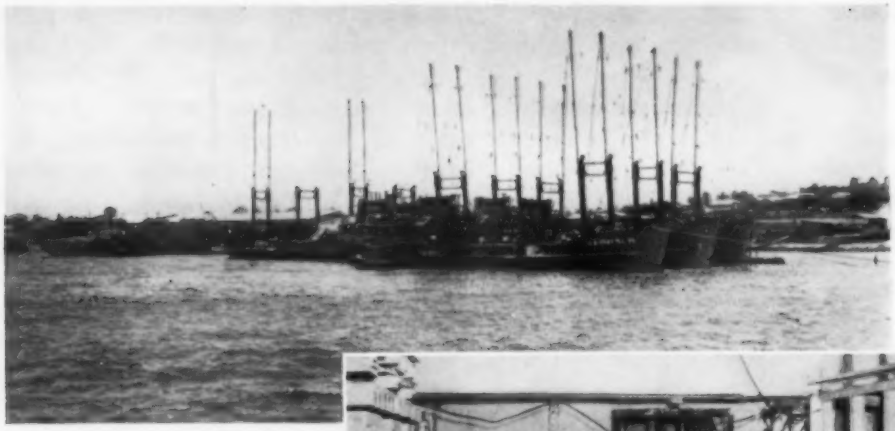


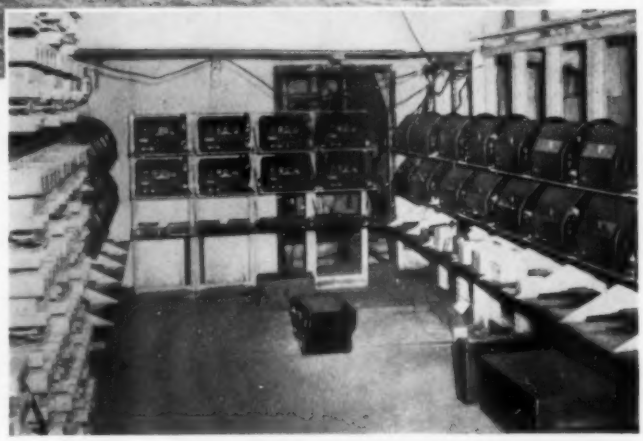
Interior of one of the trailers shown in the preceding picture

"*Sigcircus*" *Afloat*

THE ROUGH TERRAIN and transportation difficulties experienced early in the New Guinea campaign pointed to the need for more mobile equipment. But mobile installations like the "Sigcircus" caravan used in Europe would have been useless in lands where roads were mountainous or nonexistent. So the Signal Corps went to sea. A complete "Seaborne Communications Center" was built in two large barges, one containing the radio transmitter and the other the receiver and terminal equipment. These barges, together with two others housing less complex equipment for shorter circuits, and a mother ship with quarters for technical and operating personnel, were first moored in Humboldt Bay, near Hollandia, New Guinea.

Here again the leap-frogging technique was used. The barges were planned to arrive at a new headquarters as soon as possible, to furnish communications until land-based stations could be built. Then the barges were released and towed forward. In this manner the Signal Corps "navy" moved on from Hollandia to Manila, and then to Tokyo—the last





"Sigcircus" afloat: the Signal Corps' complete "Seaborne Communications Center" used in the Pacific. Right: Teletypewriter equipment installed in one of the barges

of the series of islands that once had seemed endless.

New Developments

INVENTIVE MINDS found the multichannel system to be an excellent springboard for new ideas. "Top secret" or even "restricted" radiograms must be encrypted to conceal their contents from enemy eyes. Initially this was a tedious job which took much time and labor. Ways were found to do this work automatically and instantaneously, and with the requisite security.

Another development was a teletypewriter conference service to meet the occasional need for instantaneous "back-and-forth" communication, in which questions and answers could be exchanged rapidly. For this purpose, special teletypewriters in private rooms were connected to an overseas channel, and staff officers at each terminal exchanged questions, answers, and information. Over a direct connection of this kind between a crude shelter in New Guinea and a luxurious room during the Roosevelt-Churchill conference in Quebec, General MacArthur set the date for the invasion of the Philippines.

It was also found possible to transmit telephotographs over the system without interrupting or interfering with teletype traffic, and many of the best Signal Corps news photographs reached the American press in this

way, only a few hours after the click of the camera.

Extensions of the System

A SIGNAL CORPS officer felt that it should be possible to build a jeep-like radio teletype system which would use some of the principles of the multi-channel system to provide a single channel for use on secondary routes. The Department of Operation and Engineering and the Bell Laboratories studied this problem and submitted plans and designed a system. Then, in June 1943, the first single-channel system was rushed into service between Miami, Florida, and Boriquen Field, Puerto Rico.

So successful was this system that several hundred of them were manufactured and installed at top speed. War Department circuits to oversea commands such as those in Panama, Trinidad, Brazil, and Central Africa were quickly converted to teletype operation. So were the circuits between the several Theater Headquarters and their subordinate bases. Extensions from Asmara to New Delhi and thence to Brisbane and Manila completed the girdling of the globe.

Since all messages were received in the form of a printed and perforated tape, it was a simple matter to relay a message on to another distant point, over either a wire or radio teletype circuit, without retyping. Thus a multitude of wire and radio circuits throughout the world were integrated into a single efficient communications system: the Army Command and Administrative Network. A request for a critically needed airplane part could be typed at an airfield in China, relayed at New Delhi, Asmara, and Washington, and received at Wright Field, Ohio, all within a matter of minutes.

AT EACH of the now famous "Big Three" conferences, radio teletype service with Washington and the rest of the world was available within a few steps of the conference room. Even in such far-off places as Cairo and Tehran, President Roosevelt, General Marshall, and others of the American delegation were in close touch with Washington and with our commanders in the theaters of war. Every day they received voluminous reports of the current military situation on all fronts.

Radio teletype needed no salesman. Whenever a communications officer saw it in action, he instantly saw other applications for it within his own field. The initial single-channel circuit between Miami and Puerto Rico soon became a link in an independent worldwide network operated by the Army Airways Communications System for the control of planes flying the air transport routes. Air Forces used radio teletype for the coördination of long-range bombing missions from widely separated bases. A channel between Washington and Moscow gave these nerve centers dependable communication for both diplomatic and military traffic. And still demands for additional circuits arose daily.

An Important Contribution to the War Effort

ONLY THE collapse of Japan brought this expansion to an end. Then reconversion began. Multi-channel equipment no longer needed overseas was installed in the Army stations at

Contrasts: The City Hall in Manila (left). After heavy shelling during the recapture of the city, it became the American Headquarters and message center. The building fronting on the palace moat in Tokyo (below) is now the Headquarters and message center of the Supreme Commander for the Allied Powers

Washington and San Francisco to operate with occupation forces and permanent bases. The Long Lines facilities were released, and were quickly returned to their post-war task of furnishing overseas telephone service. They were to be kept busy for many months to come, carrying calls between thousands of lonely servicemen overseas and their folks at home.*

* See "Three-Minute Furloughs," MAGAZINE, Spring 1946.

In a presidential citation which accompanied the award of the Medal for Merit to President Walter S. Gifford of A. T. & T., radio teletype was given a prominent place as one of the Bell System's most important contributions to the war effort. Its development had enabled the Signal Corps, during the most difficult period in its history, to live up to two important slogans: "Get the Message Through," and "Security, Accuracy, and Speed."

THE SCIENTISTS at the Bell Telephone Laboratories . . . were handed the job of focussing radio *micro-waves* into a narrow beam to transmit the impulses of sight and sound from one place to another. These micro-waves, you see, have a habit of shooting off in all directions, going on and on out beyond the horizon into the wild blue yonder. The problem was to herd them together so that, literally, they would "stay on the beam" over the distance that separates the relay stations. That was no small task when you realize that beams sharper than a searchlight are needed.

But—the problem *was* solved. Bell Laboratories scientists designed a metal *lens* which can focus these micro-waves much as a magnifying glass collects the sun's rays to burn a hole in a piece of paper. With this new lens, the micro-waves can be focussed into the sharpest beam of its kind ever produced, so that radio photos, radio broadcasts, and television may be transmitted more clearly, and with freedom from static and other interferences.

Bell Laboratories' scientists and their associates explore every scientific field which offers hope of bettering communications. That's one big reason why your telephone service has continued to improve throughout the years. And why it will be even better as time goes on.

From an announcement on the "Telephone Hour" radio program

The Special Knowledge, Skills, and Form of Organization Of the Bell System's Research Unit Contributed in Many Ways to the Prosecution of the War

Bell Laboratories' Rôle in Victory

Part II

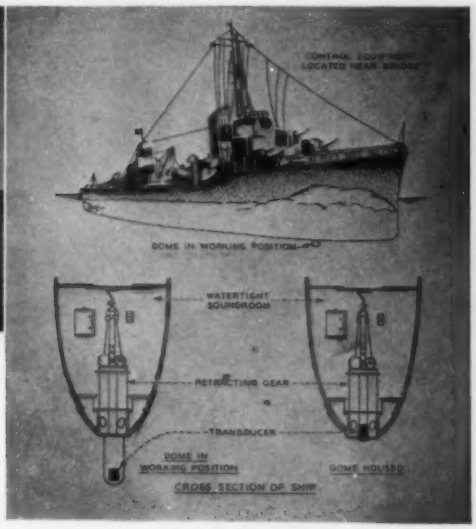
Editors' note: Several of the Laboratories' major contributions to the Allied Nations' victory over the Axis powers were described under the above title in the preceding (Spring) issue of this MAGAZINE. The following paragraphs, compiled after a survey of all the Laboratories' many and varied war-time projects, summarize as much of the rest of the story as may be told within the limits of military security.

DURING WORLD WAR I, a group of Bell Telephone Laboratories men had been active in studies of underwater sound; and when the clouds of World War II gathered, their successors began to think along the same lines. When the Laboratories entered the SONAR program, the greatest need was for precise methods of measuring underwater sound, a field in which little quantitative work had been done. Yet this was an important aspect, for precise measurement is a fundamental factor in good development and design of any equipment. With their broad experience in the measurement of ordinary sound in the development of telephony, Laboratories engineers undertook investigations which laid the groundwork for the standardization and improvement of sonar techniques.

In 1941 and 1942 they established the first lake calibration stations, one in New Jersey and the other in Florida. These were later taken over by the National Defense Research Committee as the national standardizing laboratories for underwater sound.

Sonar locates hostile submarines by projecting a beam of vibrations through the water and observing the

Above: the "Elcovee," a floating laboratory used in the development of sonar

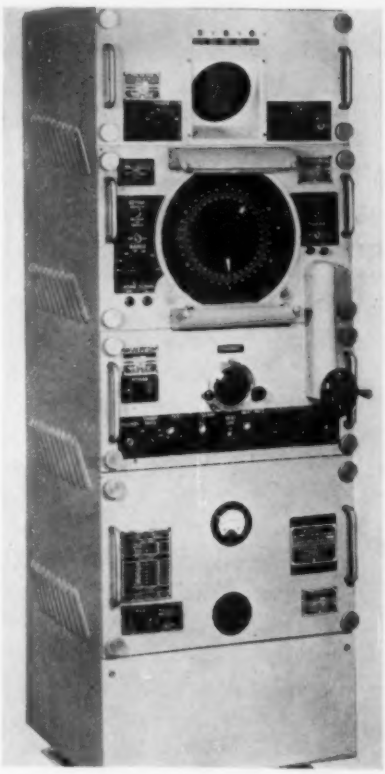


Right: How the sonar "antenna" is lowered and retracted

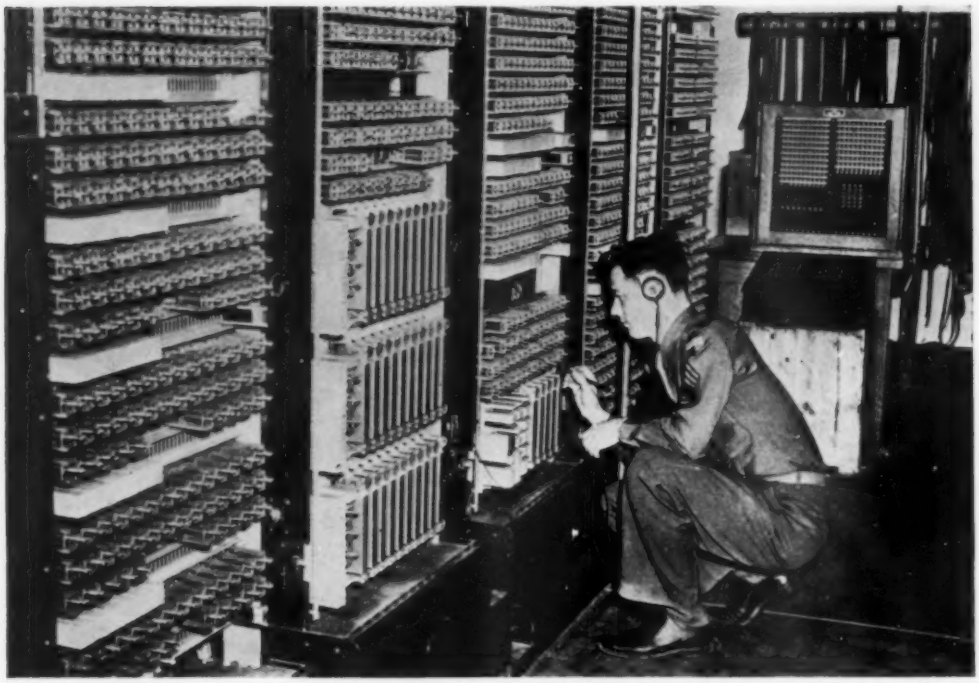
time and direction of the echo. The principle is the same as that of radar but the vibrations are of water molecules, and the frequencies are measured in tens of thousands instead of millions. Most difficult part of the job was to devise a transducer, a device to convert electrical vibrations to mechanical and vice versa. The Laboratories developed a synthetic piezoelectric crystal for this, and with Western Electric worked out a procedure to make it in very large quantities.

Another contribution was a dome to be attached to the ship's hull to house the transducer. Its streamlining and other features minimized noise pick-up—a very important factor. About three-score different transducers were designed for special uses.

Equally important was the Laboratories' contribution in the form of good design of the sonar circuits, which generated the high frequencies, broke them up into pulses, timed the returning pulses and directed them



Sonar equipment developed for installation aboard ship



The relay computer used by the Army to perform complicated mathematical computations. Note the "problem" tapes on the rack at the right

into the indicating circuits. Sonars of Laboratories' design were installed on every type of naval ship.

The thoroughness and versatility of the Laboratories' sonar development work were demonstrated when, midway through the war, its scientists were called upon to change completely the emphasis of their investigations. During the first part of the war, the problem had been one entirely of using sonar to combat German U-boats. With the winning of the Battle of the Atlantic, the emphasis changed to the Pacific theater, where Allied submarines were in the position that German underseas craft had occupied in the Atlantic; that is, using sonar on submarines to attack merchantmen and warships.

CIRCUITS have always been one of the Laboratories' special interests. Some years before the war, a scientist and an engineer teamed up to develop a circuit that would do sums in arithmetic. Starting with a problem typed on a keyboard, the relays would click for a few seconds and out would come the answer, neatly typewritten.

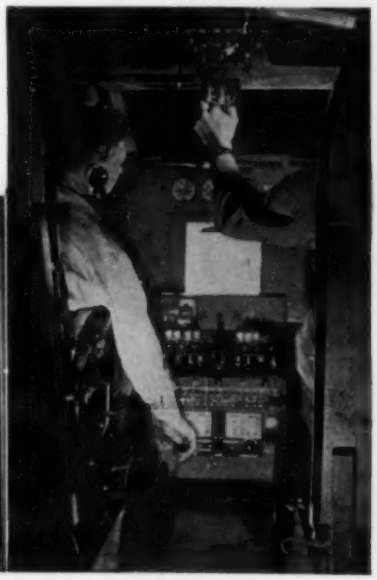
During the war, a need arose for hundreds of computations of the path taken by an anti-aircraft shell, in order to check the performance of the electrical gun director. A computer made up of relays and teletypewriters was developed, and one was built for the Army and one for the Navy. These computers employ a punched tape to direct the apparatus, tape on

which the problem is recorded, and other tapes carrying such tables as sines and logarithms. The machine will run for hours unattended. If it spots an obvious mistake which makes a problem insoluble, it will make a note and pass on to the next problem.

A PROBLEM of another kind is posed by an airplane in flight. Given a sudden updraft, the pilot will "nose down" to maintain altitude; the plane will pick up speed, and so on. Many of these variables are indicated on instruments, and the skilled "instruments" flyer can hold an even course by their aid. To teach the art, a number of "trainers" had been built which were "mock-ups" of an airplane, with linkages—mostly mechanical—between the instructor, the instruments, and the control.

With the desire to set up a working replica of a medium bomber which would provide training for a flight crew of five, the Navy asked the Laboratories to develop an all-electrical trainer. Preliminary work for the circuit engineers involved a study of aerodynamics, and the working out of equations which would connect throttle opening, propeller pitch, elevator setting, and plane load with rate of climb—to name only one set of relations. When installed in a stationary mock-up of the airplane interior, complete with noise and vi-

The flight instructor can create conditions within the trainer which simulate those found aloft

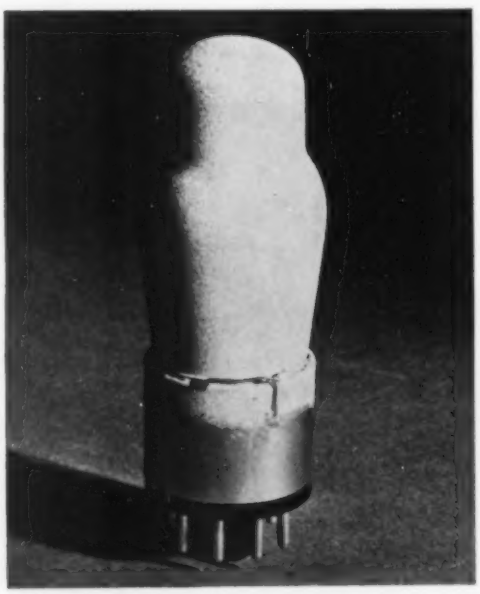


Telephone relays, vacuum tubes, and switches (below) interconnect the controls and instruments of the flight trainer. Right: Pilot and co-pilot, at the controls of the Navy trainer, can encounter all the problems—and most of the sensations—met in actual flight

bration, the effect was so realistic that more than one experienced flyer left the ship in a sweat after the instructor had given him a real workout.

As MIGHT be expected, the Laboratories' long experience with vacuum tubes was of great value to the war effort. Out of all the electronic development which was going on, one small but dramatic incident emerges. A group of repeater stations had been captured in Germany, intact except for the tubes. Signal Corps men, ransacking employees' lockers, had found one tube which fitted the sockets. In a few days that tube was in the Laboratories; in three days more, eight replicas had been built and were on their way to the front for service tests.

Western Electric did not wait for results to filter back, however; they turned out a thousand tubes in three weeks. Confidence in the Laboratories was well rewarded; the design was right, and the tubes restored service on an important European cable route.



This replica of a German vacuum tube was produced in the Laboratories in three days

ONE OF the Laboratories' earliest concerns was to eke out the supply of scarce materials by providing substitutes. One acute shortage was in tin; the metallurgists reduced the tin content in solder and developed new procedures to make good joints with this tricky alloy. Rubber was replaced by synthetics, of which the rubber chemists had wide knowledge. The zinc die casting of the combined telephone set was replaced by a plastic molding, again based on accumulated knowledge. Mica had been selected for capacitors on the basis of its appearance; feeling that much good mica was being rejected, physicists worked out electrical tests which proved so much mica usable that the shortage was alleviated.

EARLY in the war, when coastal cities were seriously concerned about air raids, the Laboratories was asked to develop a powerful warning siren. The one it produced had an engine-driven blower, a rotor or "chopper" driven by a second engine, and a sextuple horn to deliver the interrupted puff to the air. One was installed on the highest building in Radio City, New York, and several more in other cities.

AS A SUPPLEMENT to wire circuits in the communications zone, the Laboratories developed a micro-wave radio system operating at about 5,000

When mica was selected on the basis of electrical tests (above), rather than of appearance, much more was found to be usable.

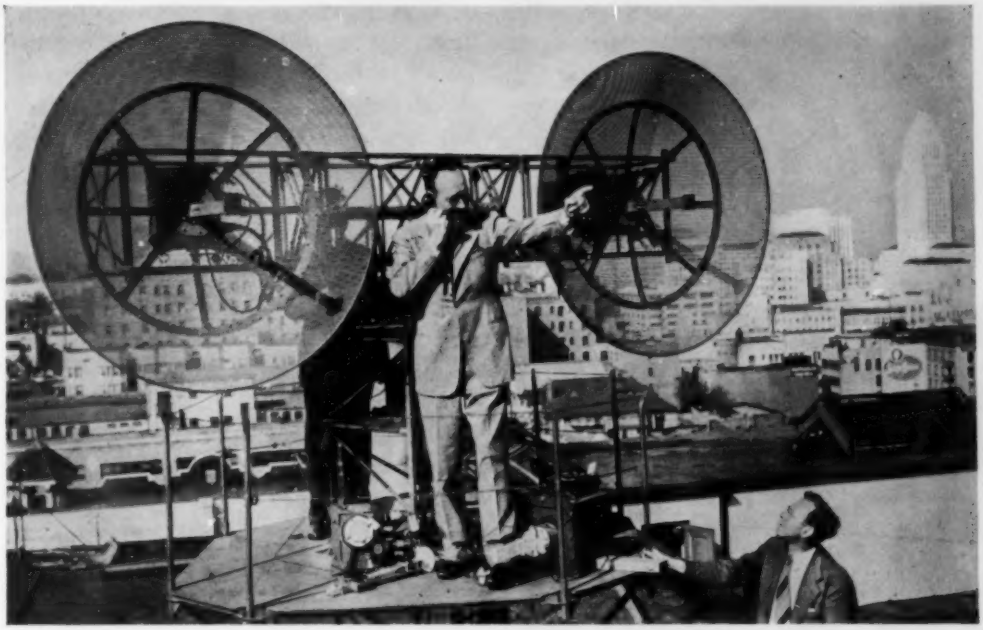
Right: A Western Electric worker adjusts silvered mica capacitors

It produces the loudest man-made sustained noise: the Laboratories' air-raid warning siren, shown here on its way to a roof-top installation

megacycles. At that frequency, the waves behave like those of light, and a clear straight-line path is required. Waves are directed into a concentrated beam by a parabolic reflector and concentrated into the receiving system by a similar reflector. At both ends the reflectors are raised on light portable towers which are preferably mounted on hilltops. A number of these systems were built by the Western Electric Company, and were installed near the end of the war in South Germany and functioned well; one link was over 100 miles long, from Heidelberg to the Zugspitze. Usually, however, links are about thirty miles long. Systems of this type are now in Bell System service, linking Nantucket and Catalina Islands to the mainland.

MANY telephone devices, such as relays, operate at speeds too high for the eye to follow. Motion pictures, taken at high speed and slowed down in projection, form a "time microscope" which has been valuable in studies of relays, ringers, handset breakage and the like. So useful proved a high-speed camera developed in the Laboratories that Western Electric marketed it under the name of "Fastax." In one form it uses 16 mm. film and operates as fast as 4,000 pictures a second; in another form it uses 35 mm. film for a wider picture. This camera has had wide application to war work. So well did "Fastax" perform on atomic bomb researches that about 60 cameras recorded the test at Bikini this summer,

In Germany: a relay point on a micro-wave radio system. Several of these systems were used by American forces, and proved very satisfactory



On the Pacific coast: Mainland antennas of the new peacetime radio telephone installation to Catalina Island

with an engineer from the Laboratories on hand to service them.

FOR SOME YEARS the Laboratories has been interested in the thermistor, a device whose resistance changes rapidly with change in temperature. Since resistance can be measured with great accuracy, the thermistor could be the heart of an instrument to measure extremely small changes in temperature. Devices were worked out which could be used to detect ships, vehicles, and even men at a few hundred feet by the difference in temperature between them and their environment.

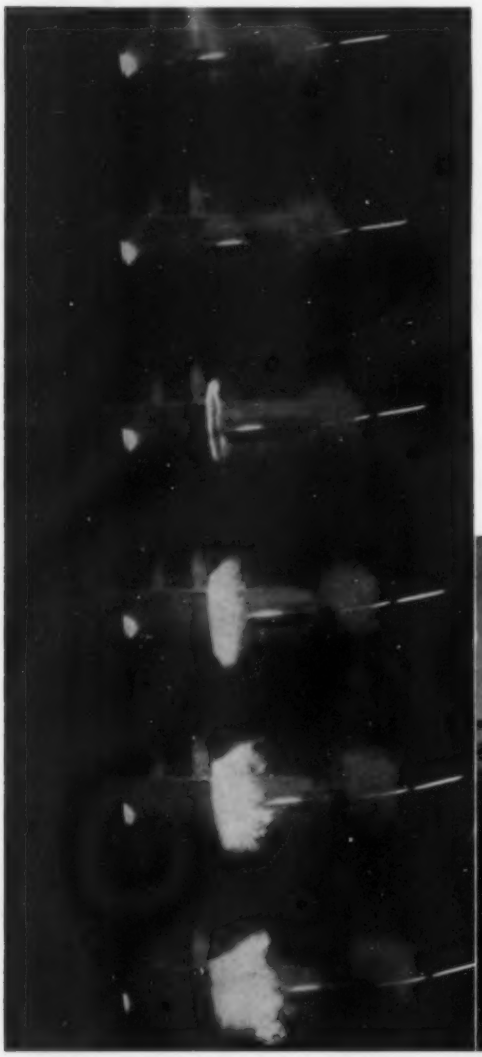
ONE OF the pre-war problems in micro-waves had been to detect extremely minute amounts of such energy. The vacuum tube was unsuitable because its own noise level was too high. Recalling the crystal detector of the early days of radio, the engineers studied and developed it into a thoroughly reliable device. They learned how to make the crystalline silicon, and even what impurities were important. When radar came along, the crystal detector was ready.

THE "AERIAL DOODLE-BUG" for finding and tracking submerged enemy submarines was developed by the Laboratories in conjunction with the Naval Ordnance Laboratory and is expected to find important peacetime application in aerial prospecting for oil and mineral deposits. This airborne magneto-meter has been credited with being an important weapon in the crucial struggle against enemy submarines, because it could detect the great masses of iron in

submarines when they were submerged too deeply for ordinary aerial observation.

In its peacetime application it provides the means for a quick large-scale survey of geological structure of the earth's surface, and thereby may provide clues for the discovery of new oil and mineral deposits. For this sort of work it has been combined with SHORAN, a radar mapping device, and special mapping cameras.

A MAGNETIC FUZE for mines was another development of the Laboratories, and about 12,000 mines equipped with it were dropped by airplane in shallow water in Japanese shipping lanes. The magnetic fuze was based on the Laboratories' earlier invention of permalloy, an alloy which is remarkably sensitive to magnetism. As a mine lay on the bottom, the permalloy in the fuze responded to the change in magnetism when a ship passed within lethal range. The fuze was so designed that it could count off and pass the first ship or several ships in a convoy and blow up the next one to pass. Mines equipped with this fuze destroyed about 300,000 tons of shipping, and many more tons were neutralized by fear of the mines.



How a rocket flies (left): pictures taken at the rate of 4,000 per second. Right: A Fastax camera in the laboratory, about to photograph dial telephone switching equipment which moves faster than the human eye can see

To use highly technical developments effectively in combat required that they be handled and serviced by skilled men. Shortly after Pearl Harbor, the Services directed the Laboratories to set up a school for war training in which key men would be prepared to train others in military schools. A few maintenance men were also to be trained, to care for the first equipments until the military schools' trainees were available. The first class started in April 1942, and from then until the end of the war a stream of trainees went through the school. They ranged from radio repairmen fresh from their work benches to graduate engineering officers who had had months of training at Massachusetts Institute of Technology. There was a steady procession of apparatus, too. Nearly every radar developed by the Laboratories appeared in the School—frequently Serial No. 1, just off the production line. For each equipment there was a special textbook, often written by the school's faculty. In all, some 125 courses were given to a total of 4,400 students.

A thermistor bolometer, useful in measuring minute changes in temperature

The Laboratories was often drawn upon for technical or administrative skill to serve the Forces as civilians. Numerous committees had Laboratories men as members or chairmen; several men had long leaves of absence. About eighty men went overseas, some of them on lengthy assignments to act as technical advisers; others on shorter investigations.

A silicon crystal in its holder (greatly enlarged). It was important in radar

Gather together a group of experienced people of outstanding qual-

An airborne magneto-meter, otherwise known as an aerial doodlebug. Suspended below a plane, it hunted out submarines beneath the surface

ity and specialized skills and of naturally coöperative instincts, infuse them with the spirit that disregards working hours, and there follows an output of new technical tools of war far beyond what anyone could have predicted. As their friends and associates return from fighting fronts, the men and women who staffed the Laboratories are proud to hear of the performance of the tools they contributed to Democracy's arsenal.

At the Laboratories' school for war training, some 125 courses were given to a total of 4,400 men

"Now We Are All Happy . . ."

IN THE MAGAZINE for Winter 1944–45, "More and Better Telephone Service for Farmers" outlined the Bell System's program for rural expansion—which has been making great strides ahead since the advent of peace. The following letter, written to a rural development representative in Georgia, expresses what the extension of service means to one family to which the telephone has but recently reached out:

"I have always loved telephones and have dreamed since childhood of having one in our home. . . . When I first went away to school, I wished we had a telephone. Then when I started working away from home I began to realize how very much telephone service was needed. But it was on my return from overseas service in World War II as a Wac that I felt this need the most.

"The minute I landed in the United States I wanted so much to call my family, to hear my mother's and daddy's voices. I felt sad when other Wacs and soldiers were lining up to call home. I could only send a telegram, which could not be answered for security reasons. I definitely decided I would have a telephone installed in our home at the first opportunity.

"On April 30, 1946, my dreams came true, and our telephone was installed in spite of the fact that mother and daddy could not agree with me that we needed one. They said they had gotten along without one for 75 years and asked, 'Why get one now?' Their ages alone present one reason for the need.

"The first night after our service was connected, I placed chairs for mother and daddy at the telephone and my sister and I stood while we called every member of our big family: a brother and family in Birmingham, Ala., a brother and family in Washington, D. C., a sister and family in Atlanta, Ga., and a brother and family in Decatur, Ga.

"It was quite a thrill to see mother's and daddy's faces brighten up as they heard each voice. It was a picture I shall never forget.

"After the calls were completed, I asked mother and daddy how they felt about having a telephone now. They answered smilingly. 'It seems as though we have seen each one of our children.'

"That sold them, and now we are all happy we have telephone service."

On the Matter of Reports

TO DO OUR WORK, we all have to read a mass of papers. Nearly all of them are far too long. This wastes time, while energy has to be spent in looking for the essential points. I ask my colleagues and their staffs to see to it that their reports are shorter.

(i) The aim should be reports which set out the main points in a series of short, crisp paragraphs.

(ii) If a report relies on detailed analysis of some complicated factors, or on statistics, these should be set out in an appendix.

(iii) Often the occasion is best met by submitting not a full dress report, but an aide-memoire

consisting of headings only, which can be expanded orally if needed.

(iv) Let us have an end of such phrases as these: "It is also of importance to bear in mind the following considerations," or "Consideration should be given to the possibility of carrying into effect." Most of these woolly phrases are mere padding, which can be left out altogether, or replaced by a single word. Let us not shrink from using the short expressive phrase, even if it is conversational.

Reports drawn up on the lines I propose may at first seem rough as compared with the flat surface of officialese jargon. But the saving of time will be great, while the discipline of setting out the real points concisely will prove an aid to clear thinking.

WINSTON CHURCHILL

IT TAKES time and money and the patient effort of supervisors to inform employees of the reasons behind routines and about the fundamental policies of the company, and about anything else which they are likely to be asked by the public. Yet without adequate knowledge to answer, they cannot make the company appear reasonable and it is more difficult for them to be polite and helpful. To have such knowledge spread down through the ranks of an organization means that from the foreman up to the top management, all supervisors must look upon the process as one vital to the success of the business. Being reasonable and polite to the public must be done by the company as a whole. It is not a gesture—it is a way of life.

From "The Bell Telephone System," by Arthur W. Page, Vice President, A. T. & T. Co. Harper & Brothers, publishers, 1941.